

Chapter 4

Criteria Derivation

Chlorpyrifos

4-1.0 Basic information

Chemical: Chlorpyrifos (Fig. 4.1); O,O-diethyl O-(3,5,6-trichloro-2-pyridinyl) phosphorothioate

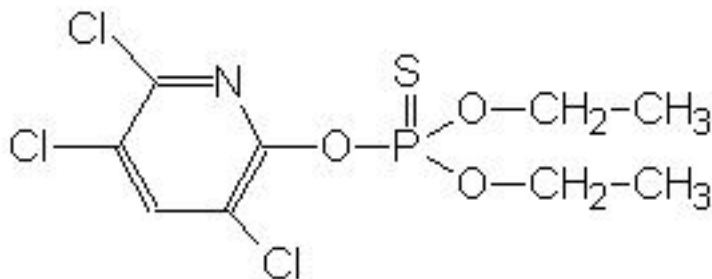


Figure 4.1 Structure of chlorpyrifos.

Trade names: Brodan, Chlorban Insect Granules, Detmol UA, Dowco 179, Dursban, Empire, Equity, Eradex, Killmaster, Lentrek, Lock-On, Lorsban, Pageant, Piridane, Pyrinex, Scout, Stipend (EXTOXNET 1996; Racke 1993)

CAS Number: 2921-88-2

USEPA PC Code: 059101 (PAN 2006)

CA DPR Chem Code: 253 (PAN 2006)

4-2.0 Physical-chemical data

Molecular Weight

350.6

Water Solubility

2 mg/L @ 23°C (Hummel & Crummet 1964);

1.12 mg/L @ 24°C (Felsot & Dahm 1979);

1.39 mg/L @ 25°C (Drummond 1986);

Geometric mean: 1.46 mg/L

Melting Point

41.5-44°C (Bowman & Sans 1983; Brust 1964; 1966; McDonald *et al.* 1985; Rigterink & Kenaga 1966);

Geometric mean of extremes: 42.73°C

Density

1.44 g/mL @ 20°C (Tomlin 2003, original reference not given)

Vapor Pressure

1.875 x 10⁻⁵ mm Hg (2.5 x 10⁻³ Pa) @ 25°C (Brust 1964);
1.8 x 10⁻⁵ mm Hg (2.4 x 10⁻³ Pa) @ 25°C (McDonald *et al.* 1985);
2.03 x 10⁻⁵ mm Hg (2.7 x 10⁻³ Pa) @ 25°C (Chakrabarti & Gennrich 1987);
Geometric mean: 1.90 x 10⁻⁵ mm Hg (2.36 x 10⁻³ Pa)

Organic carbon-water partition coefficients

log K_{oc}: 3.93 (Racke 1993, mean of values ranging from 3.00-4.49)
log K_{oc}: 4.196 (Spieszalski *et al.* 1994)
Geometric mean: 4.06

Henry's constant (K_H)

0.897 Pa m³/mol = 3.65 x 10⁻⁴ dimensionless (from Wu *et al.* 2002, original source not cited);
0.420 Pa m³/mol = 1.7 x 10⁻⁴ dimensionless (Fendinger & Glotfelty 1990);
0.676 Pa m³/mol = 2.76 x 10⁻⁴ dimensionless (Tomlin 2003, calculated from vapor pressure and solubility);
0.660 Pa m³/mol = 2.7 x 10⁻⁴ dimensionless (Downey 1987)
Geometric mean: 0.640 Pa m³/mol = 261 x 10⁻⁴ dimensionless

Log K_{ow}

4.96 (Sangster Research Laboratories 2004)

Bioconcentration Factor

2.1 x 10⁴ L/kg in three-spined stickleback (lipid-based, Deneer 1994);
1,847 L/kg in guppies (Welling & Devries 1992);
1700 in fathead minnows (unitless, Jarvinen *et al.* 1983);
727-1143 in Japanese medaka (unitless, Rice *et al.* 1997);
1.0-5100 in yeast to gulf toadfish; many based on muscle tissue with equilibrium conditions not confirmed, some lipid-normalized (Racke 1993).

Biomagnification Factor

0.7, 0.5 and 0.3 after 9, 16, and 32 days, respectively, of bioaccumulation study; values are lipid-based (Varó *et al.* 2002).

Environmental Fate

Hydrolysis half-life @ 25°C: 22.8 d, 35.3 d, 62.7 d @ pH 8.1, 6.9 and 4.7, respectively (Meikle & Youngson 1978);
Hydrolysis half-life @ 35°C: 4.5 d, 11.5 d, 15.7 d @ pH 8.1, 6.9 and 4.7, respectively (Meikle & Youngson 1978);
Hydrolysis half-life @ 15°C: 54.2 d, 99.0 d, 210 d @ pH 8.1, 6.9 and 4.7, respectively (Meikle & Youngson 1978);
Hydrolysis half-life @ 25°C: 73 d, 72 d, 16 d at pH 5.0, 7.0 and 9.0, respectively (McCall 1986);
Hydrolysis half-life @ 25°C: 74 d at pH 7.0 (Batzner *et al.* 1990);
Hydrolysis half-life @ 20°C: 120 d, 53 d @ pH 6.1 and 7.4, respectively (Freed *et al.* 1979);
Hydrolysis half-life @ 25°C: 54 d, 142 d, 10 d at pH 5.9, 6.1 and 9.8, respectively (Macalady & Wolfe 1985);
Volatility from water half-life = 3.5-20d (McCall *et al.* 1984; Neely & Blau 1977);
Photolysis (aqueous) half-life: 13.9 d, 21.7 d, 13.1 d at pH 5.0, 6.9, 8.0, respectively @ 25°C (Meikle *et al.* 1983);
Photolysis (aqueous) half-life: 31 d in midsummer at 0.001 cm depth; 345 d in midwinter at 0.001 cm depth; 43 d in midsummer at 1 m depth (Dilling *et al.* 1984).

4-3.0 Human and wildlife dietary values

Food tolerances and FDA action levels not established (USEPA 2000a; 2002; USFDA 2000).

Wildlife LC₅₀s (dietary) for animals with significant food sources in water

Mallard duck: 136 mg/kg (Stevenson 1965; cited in USEPA 2000c)
203 mg/kg (Roberts & Phillips 1987; cited in USEPA 2000c)

Wildlife dietary NOECs for animals with significant food sources in water

Mallard duck: 46 mg/kg (Fink & Beavers 1977; cited in USEPA 2000c)
30 mg/kg (Hakin 1990; cited in USEPA 2000c)
25 mg/kg (Fink *et al.* 1978; cited in USEPA 2000c)

These wildlife values were cited in USEPA (2000c), but are in unpublished reports. Original references could not be found. No other dietary values were found for chlorpyrifos.

4-4.0 Ecotoxicity data

Using data sources in Tables 3.1 and 3.2 (Chapter 3), approximately 340 original studies of the effects of chlorpyrifos on aquatic life were identified. Most of the single-species effects studies identified for this criteria derivation were summarized using the

form shown in Figure 3.4 (Chapter 3). Information in these summaries was used to evaluate each study for relevance and reliability based using the rating systems described in the methodology (Chapter 3; section 3-2.2). Some chlorpyrifos studies were deemed irrelevant from an initial screening and were not summarized (e.g., studies not using whole-animal exposures). Ecosystem-level studies were not summarized due to their complexity. Many mosquito studies were conducted according to methods described by the World Health Organization (WHO 1963), but this methodology was judged unacceptable by more recent standards due to such things as allowing use of deionized water as a dilution water, using 4th instar larvae rather than 2nd-3rd instars as required by ASTM (2005) and USEPA (2000b), and allowance of use of as much as 1 mL of carrier solvent per 100 mL test solution (various ASTM methods allow only 0.1 mL/L and 0.5 mL/L for chronic and acute tests, respectively). Therefore, studies citing WHO methods were not given credit for following an acceptable standard (or equivalent) method. Copies of completed summaries for all studies rated relevant and reliable (RR) for criteria derivation are included in Appendix 4B of this chapter.

Using the data evaluation criteria, 29 acute studies yielding 68 toxicity values were judged relevant and reliable for criteria derivation (Tables 4.1 and 4.2, at the end of this report). The Chinook salmon study by Wheelock *et al.* (2005) did not calculate an LC₅₀ value, but raw data were available and a value was calculated using the trimmed Spearman-Kärber method (Hamilton *et al.* 1977; USEPA 2006). Similarly, 96-h raw data from a chronic *Ceriodaphnia dubia* study (CDFG 1999) were used to calculate an LC₅₀ of 0.0396 µg/L. Chronic studies for four species yielding 20 toxicity values were both relevant and reliable (2 crustaceans, 1 insect, and 1 fish; Tables 4.3 and 4.5). Eighteen studies were rated RL, LL, or LR, where L = less relevant or less reliable, and may be used as supplemental information for evaluation of derived criteria (Table 4.6).

All of the freshwater plant studies that were found used formulations of chlorpyrifos and had other problems resulting in ratings of N for either relevance or reliability, or both (Birmingham & Colman 1977; Butcher *et al.* 1977; Samson & Popovic 1988; Van Donk *et al.* 1992), while all of the tests with chlorpyrifos of ≥ 80% purity were for saltwater species (Borthwick & Walsh 1981; Walsh *et al.* 1988). Thus, no plant studies of chlorpyrifos were rated relevant and reliable for criteria derivation. Only the saltwater algal study by Walsh *et al.* (1988) was rated highly enough to be used as supporting data. This study reported EC₅₀ values of 240 and 640 µg/L for population density of *Minutocellus polymorphus* and *Skeletonema costata*, respectively. These values are orders of magnitude higher than chronic toxicity values for invertebrates and fish (Tables 4.3 and 4.6). This limited data set indicates that setting criteria without plant values should not lead to underprotective criteria.

Twenty-eight mesocosm, microcosm, and ecosystem (field and laboratory) studies were found. Most of these studies used formulations, rather than chlorpyrifos of ≥ 80% purity. Also, for many of them, chlorpyrifos levels were not measured, and other water quality parameters were not reported. Using the rating system described in section 3-2.2 of the methodology, 20 of these studies were rated R or L and may be used as supporting data (Table 4.7).

Two studies of chlorpyrifos effects on wildlife were found. Herin *et al.* (1978) studied the effects of dietary chlorpyrifos exposure in mallard ducks. No NOEC was determined because the study did not use low enough chlorpyrifos concentrations. Wilson *et al.* (1991) studied non-dietary chlorpyrifos exposure in red-tailed hawks. In this methodology wildlife data are used only to assess whether or not water quality criteria are set at levels that could cause harm to wildlife due to bioaccumulation in food items. Since neither the Herin *et al.* (1978) nor Wilson *et al.* (1991) studies produced NOEC values, they are not useful for this assessment. Additional wildlife values were found in USEPA (2000c), but original studies could not be found for review (values are listed in section 4-3.0).

Raw data were available for two acute toxicity studies (CDFG 1992g; h) with the opossum shrimp *Neomysis mercedis*. These data were used with the USEPA ACE program v. 2.0 (USEPA 2003a) to estimate chronic toxicity values (to enhance the chronic data set). Tables 4.8 and 4.9 show the raw data used for the ACE analyses. The life-cycle of *N. mercedis* is 3-4 mo (Brandt *et al.* 1993), thus the ACE model was set to estimate chronic toxicity at 120 d. For both tests, the accelerated life testing (ALT) model was used. Both *N. mercedis* tests yielded the same chronic value of 0.001 µg/L (the 120-d, 1% mortality value), which were added to the chronic data set (Table 4.3). However these values were not used to determine the chronic value, because the chronic value was calculated with an ACR and it is preferable to avoid multiple layers of estimation.

4-5.0 Data reduction

Chlorpyrifos data were reduced according to procedures in Chapter 3, section 3-2.4. Acceptable acute and chronic data that were excluded, and the reasons for their exclusion, are shown in Tables 4.2 and 4.5, respectively. The final acute and chronic data sets are shown in Tables 4.1 and 4.3, respectively. The final acute data set contains 17 species mean acute values; the final chronic set contains 3 species mean chronic values.

4-6.0 Acute criteria calculation

Since at least 5 acceptable acute toxicity values are available from 5 different families (as described in Chapter 3, section 3.1), the SSD procedure was used to derive 5th percentile values (median and 95% confidence limit), as well as 1st percentile values (median and 95% confidence limit). Using the BurrliOz v. 1.0.13 program (CSIRO 2001) a Reciprocal Weibull distribution (i.e., the limiting Burr Type III distribution when the k parameter is > 100) was fit and the following values were obtained. Some values in the acute data set were reported with one significant figure and the uncertainty seen in comparing the median estimate of the 5th percentile with the 95% confidence limit is in the first significant figure, therefore the criteria will be expressed with one significant figure.

Fit parameters: $\alpha = 0.691$; $\beta = 0.394$.

5th percentile, 50% confidence limit: 0.02429 µg/L
5th percentile, 95% confidence limit: 0.01436 µg/L
1st percentile, 50% confidence limit: 0.008163 µg/L
1st percentile, 95% confidence limit: 0.004694 µg/L

Recommended acute value = 0.02429 µg/L (median 5th percentile value)

Acute criterion = acute value ÷ 2 = 0.01215 µg/L
= 0.01 µg/L = 10 ng/L

Note: by way of example only, the assessment factor (AF) method was applied to the chlorpyrifos data set to determine the range of acute criteria that would be obtained depending on whether the data set contained 1, 2, 3, or 4 values. The acute values were derived by dividing the lowest value by the assessment factors in Table 3.13. The lowest value in the data set is 0.035 µg/L for *Daphnia ambigua* (Harmon *et al.* 2003). Since this species is in the family Daphniidae and the genus *Daphnia*, the AF method can be used. The following acute values were obtained and then divided by 2 to determine hypothetical acute criteria.

1 sample: 35 ng/L ÷ (570) = 0.061 ng/L ⇒ Acute criterion = 0.031 ng/L
2 samples: 35 ng/L ÷ 36 = 0.97 ng/L ⇒ Acute criterion = 0.49 ng/L
3 samples: 35 ng/L ÷ 7.8 = 4.5 ng/L ⇒ Acute criterion = 2.2 ng/L
4 samples: 35 ng/L ÷ 5.1 = 6.9 ng/L ⇒ Acute criterion = 3.4 ng/L

Acute values were plotted in a histogram Figure 4.2 to show the general spread of the data set. The results graph from the BurrliOZ software showing the fit of the Reciprocal Weibull distribution (a limiting case of the Burr Type III distribution) is shown in Figure 4.3, plotted in Excel (v. 9.0.6) using the fit parameters reported in section 4-6.0. The data appears to be separated into modalities. However, using a fit test based in cross-validation and Fisher's combined test, no significant lack of fit was found ($p = 0.13$, see Appendix 4C) indicating that the grouping are not distinct enough to warrant modeling them individually. Since there is not a clear indication that the data should be divided and it is preferable to use as much data as possible to characterize the distribution, the acute criterion (10 ng/L) was derived using the whole data set.

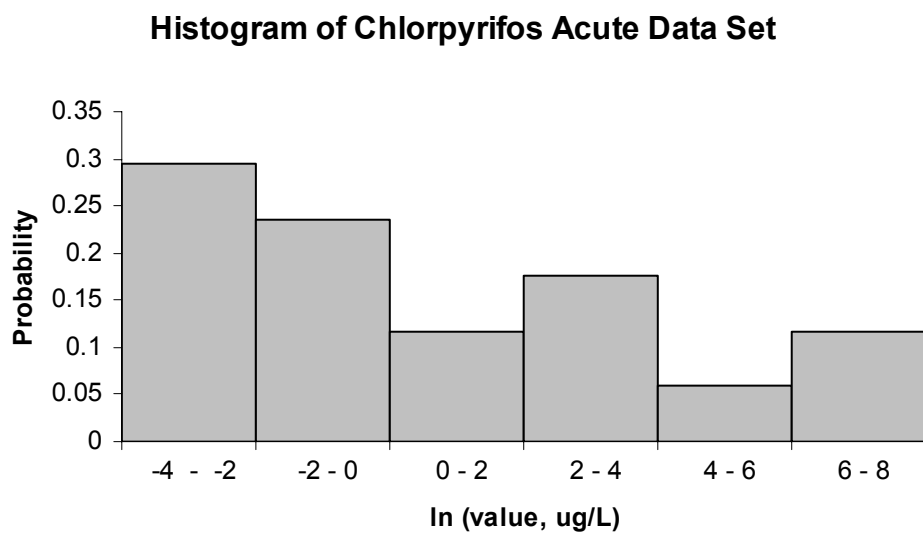


Figure 4.2 Histogram of the natural logarithm of the acute values.

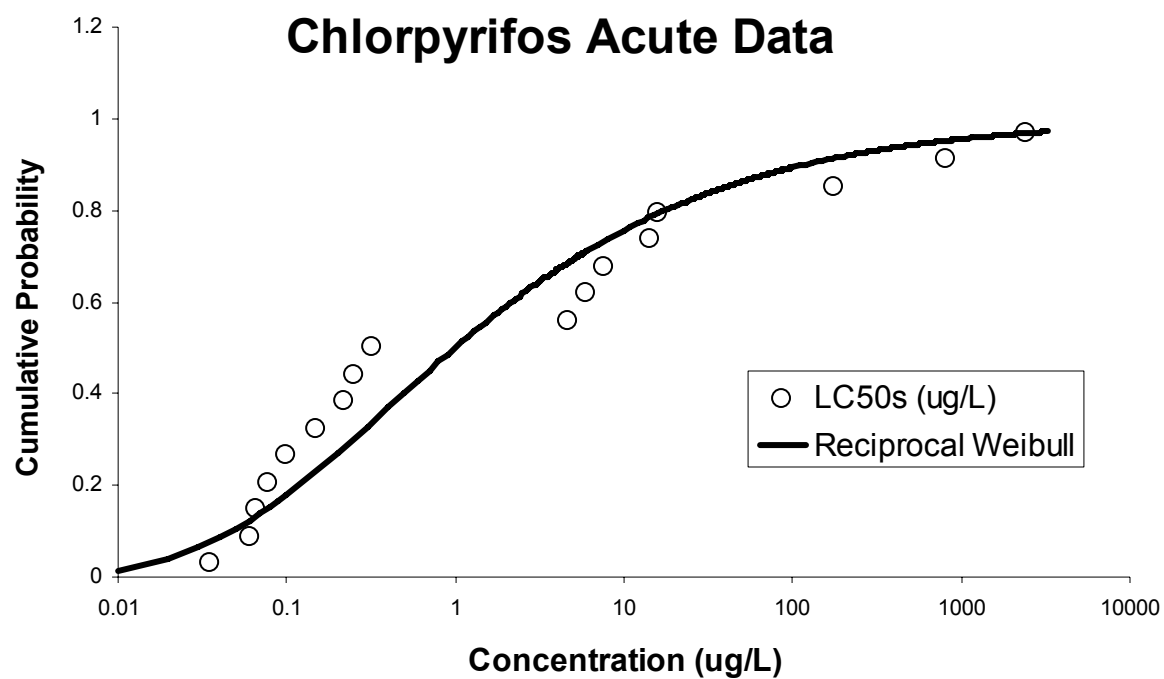


Figure 4.3 Reciprocal Weibull distribution fit to the chlorpyrifos acute data set.

4-7.0 Chronic criteria calculation

Fewer than 5 chronic toxicity values from 5 different families are available, thus the acute-to-chronic ratio (ACR) method was used. Three chronic values in the accepted (RR) data set have corresponding acute values. Two are for *Ceriodaphnia dubia* (CDFG 1994), and one is for *Pimephales promelas* (Jarvinen & Tanner 1982). To avoid excessive layers of estimation, the estimated chronic values for *N. mercedis* were not used to calculate ACRs. Since not enough freshwater data were available for calculation of the ACR, saltwater data were used to meet minimum data requirements. Among saltwater studies reviewed, acute and corresponding chronic data were available for California grunion, *Leuresthes tenuis* (Borthwick *et al.* 1985; 1985). *Ceriodaphnia dubia*, *P. promelas* and *L. tenuis* are from three different families representing two fish and one invertebrate and so can be used to calculate an ACR for chlorpyrifos. The geometric mean of ACRs for *C. dubia* is 1.0, the value for *P. promelas* is 60.9, and the value for *L. tenuis* is 5.0. The ACRs increase with increasing species mean acute values (SMAVs) for this data set, so only those values within a factor of 10 of the ACR of the species with the SMAV nearest the 5th percentile value were used to determine a final multi-species ACR of 2.2. Data used to determine the ACR are summarized in Table 4.4. The ACR of 2.2, determined by this methodology is lower than the value of 4.1 determined by the USEPA (1986) or the value of 3.5 determined by the Siepmann & Finlayson (2000). The difference in values is due to different data sets resulting from new data and/or from different data acceptability standards in the different methodologies. The acute 5th percentile value from section 4-6.0 was divided by the ACR

$$\begin{aligned}\text{Chronic criterion} &= \text{acute 5}^{\text{th}} \text{ percentile value} \div \text{ACR} \\ &= 0.02429 \mu\text{g/L} \div 2.2 \\ &= 0.01104 \mu\text{g/L} \\ &= 0.01 \mu\text{g/L} = 10 \text{ ng/L}\end{aligned}$$

4-8.0 Bioavailability

Few studies of the effects of suspended and dissolved solids on the bioavailability of chlorpyrifos are available. Phillips *et al.* (2003) found that fewer walleye survived exposure to chlorpyrifos-humic acid (HA) complexes than to either HA alone or chlorpyrifos alone, and no differences were seen in cholinesterase inhibition between chlorpyrifos-HA and aqueous chlorpyrifos exposures. In a study of chlorpyrifos binding to colloidal materials, Wu & Laird (2004) found that chlorpyrifos sorbed strongly to a calcium-humate and did not desorb, but moderately sorbed to, and desorbed from, a river sediment. They concluded that both the organic and inorganic materials in suspended sediment affect the adsorption and desorption of chlorpyrifos. These studies indicate that bioavailability of chlorpyrifos is not predictable without site-specific, species-specific data. Until such data are available, compliance with criteria should be determined on a total concentration basis.

4-9.0 Mixtures

Chlorpyrifos often occurs in the environment with other organophosphate pesticides (discussed in Phase I, TenBrook & Tjeerdema 2006). Since compounds in this class have a similar mode of action, either the toxic unit or the relative potency factor approach (Chapter 3, section 3-5.2.1) can be used to determine compliance in cases where organophosphate mixtures are present.

Several studies report greater than additive toxicity of chlorpyrifos in combination with triazine herbicides (Anderson & Lydy 2002; Belden & Lydy 2000; Jin-Clark *et al.* 2002; Lydy & Austin 2005). Chlorpyrifos synergized the action of esfenvalerate in fathead minnows, but the same response was not clear in the midge *Chironomus tentans* (Belden & Lydy 2006). Table 4.10 shows the synergistic ratios (SR) for these studies. The SR is obtained by dividing the EC₅₀ of the pesticide alone by the EC₅₀ in the presence of a non-toxic concentration of the synergist. Thus, the SR reported in these studies is equivalent to the interaction coefficient (K). SR values > 1 indicate synergistic interaction.

Since multiple SR (or K) values are available for atrazine over a range of concentrations, these values were used to derive a quantitative relationship. The JMP IN program v. 5.1.2 (JMP 2004) was used to do least squares regressions of the *C. tentans* and *Hyaella azteca* data together, which resulted in a significant relationship between atrazine concentration and K values ($p < 0.05$). The relationship is described by the following equation:

$$K = 0.008(\text{Conc. Atrazine}) + 1.27 \quad (r^2 = 0.52, p = 0.03) \quad (4.1)$$

The r^2 value is not very high, so the species were considered independently. For *C. tentans* the relationship between K and atrazine concentration was not significant ($p > 0.05$), but for *H. azteca* the following relationship was determined:

$$K = 0.009(\text{Conc. Atrazine}) + 1.12 \quad (r^2 = 0.94, p = 0.03) \quad (4.2)$$

This relationship should be used with caution due to the small data set ($n = 4$) and due to the fact that three of the four values are from the same study. The lack of a significant relationship between atrazine concentration and K values for *C. tentans* may be due to differences between studies (there were not enough data to evaluate the experiment effect statistically).

Since *H. azteca* is among the most sensitive species in the data set, it is worthwhile to use equation 4.2 to estimate K values for various levels of atrazine co-occurring with chlorpyrifos. To determine compliance, or to assess potential for harm, equation 4.3 may be used to establish the effective concentration of chlorpyrifos in the presence of atrazine:

$$C_a = C_m(K) \quad (4.3)$$

where:

C_a = adjusted, or effective, concentration of chlorpyrifos

C_m = measured concentration of chlorpyrifos in a water sample

K = coefficient of interaction, calculated for the synergist concentration in water

The effective concentration in a water sample may be compared to chlorpyrifos criteria, or may be used in one of the additivity models.

Ankley & Collyard (1995) reported reduced toxicity of chlorpyrifos to *Hyaella azteca* and *Chironomus tentans* in the presence of piperonyl butoxide (PBO), but antagonistic ratios were not reported. PBO is commonly used in toxicity identification evaluations because it is known to inhibit organophosphates by inhibiting the P450 enzymes that activate the pesticides (Ankley *et al.* 1991; Hunt *et al.* 2003). Since no interaction coefficients (K) have been derived to describe antagonism between chlorpyrifos and piperonyl butoxide, it is not possible to quantify this non-additive toxicity. Consequently, there is no way to account for this interaction in compliance determination.

4-10.0 Temperature, pH, other water quality effects

Several studies have shown increased chlorpyrifos toxicity with increased temperature (Humphrey & Klumpp 2003; Johnson & Finley 1980; Macek *et al.* 1969; Mayer & Ellersieck 1986). However, none of these studies was rated RR, so they could not be used to quantify effects of temperature on chlorpyrifos toxicity. Among chlorpyrifos studies rated RR, there are no cases of chronic tests conducted at different temperatures for the same species. There are three acute *Pimephales promelas* studies conducted at 25° C (Geiger *et al.* 1988; Holcombe *et al.* 1982; Jarvinen & Tanner 1982), one conducted at 16° C (Geiger *et al.* 1988) and one at 17.3° C (Phipps & Holcombe 1985). Least squares regression of these values shows a strong relationship of increasing chlorpyrifos toxicity with increasing temperature ($r^2 = 0.95$; $p < 0.01$). No invertebrate studies of temperature effects are in the data set.

Rainbow trout and bluegill studies (Mayer & Ellersieck 1986) included in the supplemental data table were rated highly enough (RL, LL, LR) to be used as supporting information, and can be used here for comparison to the derived criteria. For both species, the acute toxicity of chlorpyrifos increased with increasing temperature, but only for rainbow trout at 18 °C did the 96-h LC_{50} of $< 1 \mu\text{g/L}$ approach the proposed criterion of 11.5 ng/L. A definitive LC_{50} value would be needed to make a reasonable assessment of potential risks to rainbow trout exposed to chlorpyrifos at 18 °C. At 13 °C the 96-h LC_{50} for rainbow trout was 7.1 $\mu\text{g/L}$, well above the proposed acute criterion. Bluegill sensitivity was highest at the highest temperature tested (29 °C), but the 96-h LC_{50} at 29 °C was 1.7 $\mu\text{g/L}$, well above the proposed acute criterion.

Although there is evidence of temperature effects on chlorpyrifos toxicity, there are not data that were highly rated (rated RR by this methodology) to adequately quantify

the relationship at this time. Therefore, only results of tests conducted at standard temperatures (i.e., temperatures recommended in standard toxicity test methods) are included in the data set and equations are not needed for criteria expression.

4-11.0 Sensitive species

The calculated acute and chronic criteria (10 and 10 ng/L, respectively) are below the lowest acute and chronic values in the data set. The lowest acute value in either the data set rated RR, or those rated RL, LR, or LL is 35 ng/L for *Daphnia ambigua* (Harmon *et al.* 2003). The lowest measured chronic value in either data set is a maximum acceptable toxicant concentration (MATC) of 6.8 ng/L for *Mysidopsis bahia* (Sved *et al.* 1993). This value is just under the chronic criterion; however, this is a saltwater value and there were significant effects observed in the solvent control. The lowest freshwater measured chronic value in either data set is a maximum acceptable toxicant concentration (MATC) of 40 ng/L for *Ceriodaphnia dubia* (CDFG 1999). The estimated chronic value of 1 ng/L for *Neomysis mercedis* (CDFG 1992g; h) is below the calculated criterion, but the chronic criterion should not be adjusted until and unless that estimated value is supported by measured data. Both the acute and chronic criteria, as calculated, should be protective of sensitive species represented in the data sets, because they are lower than currently available data from single-species toxicity tests.

4-12.0 Bioaccumulation

Bioaccumulation of chlorpyrifos has been measured in fish and plants (Karen *et al.* 1998; Rice *et al.* 1997; Welling & Devries 1992). It has a log K_{ow} of 4.96 (Sangster Research Laboratories 2004), and molecular weight of 350.6, which further indicate its bioaccumulative potential. There are no tolerances or FDA action levels for fish tissue (USEPA 2000a; 2002; USFDA 2000), but there are a few reported dietary NOEC values for mallard ducks. As noted in section 4-3.0, all of the available mallard duck LC_{50} values from USEPA (2000c) are from unpublished studies and cannot be reviewed for reliability. Herin *et al.* (1978) was reviewed and rated L, but no NOEC values were determined.

Varó *et al.* (2002) reported biomagnification factors (BMF) of 0.7 - 0.3 (decreasing with increasing time of exposure) for chlorpyrifos in a two-level food chain experiment with *Artemia* spp. and the fish *Aphanius iberius*. These BMF values of less than 1.0, and the fact that the BMF values decrease over time, indicate that chlorpyrifos does not biomagnify. Varó *et al.* (2002) suggest that this is due to the ability of fish to biotransform chlorpyrifos and to the log K_{ow} for chlorpyrifos being < 6. Berglund *et al.* (2000) reported no biomagnification over three trophic levels for polychlorinated biphenyls with log K_{ow} values < 6.

A BCF value of 1,847 L/kg was reported for guppies (Welling & Devries 1992), but that value was obtained under inappropriate exposure conditions (14-d static). A value of 1700 (unitless) was reported by Jarvinen *et al.* (1983) for fathead minnows. Rice *et al.* (1997) reported BCF values ranging from 727-1143 (unitless) in tests with Japanese

medaka, but those values were reported after a 48-h exposure, with no confirmation of steady-state conditions. Karen *et al.* (1998) studied partitioning of chlorpyrifos between water and aquatic macrophytes, but did not determine steady-state BCF values. A lipid-based BCF value of 2.1×10^4 L/kg is provided by Deneer (1994). The highest of the non-lipid based values (1700) is used in this analysis to assess a worst-case bioaccumulation scenario.

It is interesting to note that the highest BMF of 0.7 reported by Varó *et al.* (2002) is in good agreement with the default value of 1.0 given in Table 3.15 (Chapter 3) for compounds with $BCF < 2000$.

The dietary LC_{50} of 136 mg/kg for mallards (Stevenson 1965) was translated to a water value using equation 3.19 (Chapter 3, section 3-7.1) along with a BMF value of 0.7, which represents the highest value measured by Varó *et al.* (2002), and will give a worst-case assessment :

$$NOEC_{\text{water}} = 136 \text{ mg/kg} \div (1700 * 0.7) = 0.114 \text{ mg/L} = 114 \text{ } \mu\text{g/L}$$

The proposed acute criterion is well below the $NOEC_{\text{water}}$ based on acute toxicity to mallards.

Although the original study could not be evaluated, the dietary NOEC of 25 mg/kg for mallard duck (Fink *et al.* 1978) was used to get a worst-case idea of potential chronic harm due to bioaccumulation.

$$NOEC_{\text{water}} = 25 \text{ mg/kg} \div (1700 * 0.7) = 2.1 \times 10^{-2} \text{ mg/L} = 21 \text{ } \mu\text{g/L}$$

The proposed chronic criterion is below the estimated chronic $NOEC_{\text{water}}$ value for mallard ducks. Neither the acute nor chronic criteria are expected to cause unacceptable levels of bioaccumulation.

4-13.0 Ecosystem and other studies

Twenty-one studies of chlorpyrifos effects on microcosms, mesocosm, and model ecosystems were rated acceptable (R or L rating; Table 4.7). Many studies involved one-time application of chlorpyrifos at levels well above the calculated criteria and so are not relevant for this analysis (Brock *et al.* 1992b; Brock *et al.* 1993; Cuppen *et al.* 1995; Kersting & Van Wijngaarden 1992; Rawn *et al.* 1978; Van Breukelen & Brock 1993; Van Donk *et al.* 1995; Van Wijngaarden & Leeuwangh 1989).

Ward *et al.* (1995) observed reduced abundance of macroinvertebrates within 11 d, as well as secondary effects on biomass with continuous chlorpyrifos treatment every day for 21 d at 0.1 $\mu\text{g/L}$. In tests of chlorpyrifos effects on the mayfly *Cloeon dipterum*, Van Wijngaarden (1993) found that effects were no longer demonstrable when concentrations reached 0.16, 0.2 and 0.06 $\mu\text{g/L}$ in laboratory microcosms, outdoor ponds and experimental ditches, respectively, based on 48-h laboratory exposures of *Cloeon*

dipterum to samples from each experimental habitat. At a continuous concentration of 0.1 µg/L for 7 wk, chlorpyrifos caused primary effects on species in the order Cyclopoida and on *Daphnia galeata*, and caused secondary effects on the rotifer *Keratella quadrata* (Van Den Brink *et al.* 1995). Bluegill survival was reduced by 3%, and largemouth bass by 10%, 63 d after treatment of an outdoor pond with 0.97 µg/L chlorpyrifos, compared to 1% reduction in survival in control ponds (Macek *et al.* 1972). After exposure in outdoor pond microcosms Giddings *et al.* (1997) report 3-mo IC₂₅ (25% inhibition) values for bluegill sunfish of 0.4 and 1.9 µg/L, based on survival and total biomass, respectively. In a treated pond study by Siefert (1984), the first two applications of a granular formula resulting in variable measured concentrations from 0.00 to 0.30 µg/L, which reduced or eliminated 7 species of Cladocerans and benthic invertebrates. There is no way to determine the no effect concentration in this study. However, the authors determined the lab exposure toxicities (LC₅₀s) to sensitive species (Cladocerans, Amphipods and Chironomids) were 0.1-0.40 µg/L, although those test did not rate as relevant and reliable by this method. One of the most sensitive species in that study was *Hyalella azteca* for which the acute data set contains a species mean acute value of 0.077µg/L, so the acute criteria of 0.010 µg/L should be protective.

Van Wijngaarden *et al.* (1996) report 7-d mesocosm EC₅₀ values ranging from 0.1 µg/L for *Mystacides* spp. to 2.8 µg/L for *Ablabesmyia* spp. In the same study, 7-d EC₁₀ values ranging from 0.01 µg/L for *Mystacides* spp. to 2.7 for *Ablabesmyia* spp. were reported. Van Wijngaarden *et al.* (2005) report community 4-5 wk NOECs of 0.1 µg/L in three separate laboratory microcosm experiments of chlorpyrifos exposure to plankton-dominated nutrient-rich microcosms. Similarly, species and community NOECs of 0.1 µg/L were reported from 0.1-55 wk post-treatment for macroinvertebrate and zooplankton communities exposed to chlorpyrifos in outdoor experimental ditches (Van Den Brink *et al.* 1996). Pusey *et al.* (1994) reported no effects on taxon richness for 80 d from one-time 6-h applications of chlorpyrifos at 0.1 µg/L to an outdoor artificial stream. In various measures of ecosystem metabolism Kersting & Van Den Brink (1997) report a 20-wk NOEC of 0.9 µg/L chlorpyrifos based on system oxygen concentration, a 12-wk NOEC of 6 µg/L based on system pH, and a 24-wk NOEC of < 0.1 µg/L based on gross production (mg O₂/L-d) and respiration (mg O₂/L-d). The authors acknowledge that the latter two significant findings may be due to a Type II error. Brock *et al.* (1992b) observed that model ecosystems were able to recover when concentrations of chlorpyrifos fell below 0.1-0.2 µg/L. In studies in experimental streams, Eaton *et al.* (1985) exposed macroinvertebrates, fathead minnows, and bluegills to continuous concentrations of chlorpyrifos ranging from 0.12-0.83 µg/L, and pulsed concentrations ranging from 0.94 -7.0 µg/L-d (from area under time-concentration curves). Translating the time-concentration values to apply to the 1-h acute averaging period yields range of 1-h concentrations of 22.6-168 µg/L, and a range of 4-d concentrations of 0.24-1.8 µg/L. Differences in macroinvertebrate communities were observed in both the continuous and pulsed-treated streams compared to a control stream over the 100-d duration of the study. Deformities (19.4-23.6%) were observed in fathead minnows in two samplings from the pulse exposure experiment, but no other effects were observed in either bluegills or fathead minnows.

Werner *et al.* (2000) performed laboratory toxicity tests and toxicity identification evaluations on samples collected from the Sacramento-San Joaquin River Delta. Six filtered samples exhibiting acute toxicity (measured as significant mortality in ≤ 4 d) had chlorpyrifos concentrations ranging from 0.09-0.52 $\mu\text{g/L}$ (with no other pesticides detected). Two filtered samples exhibiting chronic toxicity (significant mortality in > 4 d) had chlorpyrifos concentrations ranging from 0.058-0.068 $\mu\text{g/L}$ (with no other pesticides). Hundreds of other samples did not exhibit toxicity, implying that they had chlorpyrifos levels below those found in the toxic samples.

Given the results of these studies, it appears that an acute criterion of 10 ng/L and a chronic criterion of 10 ng/L will be protective of organisms in ecosystems. These results are not entirely conclusive because, as discussed in section 4-8.0, the potential effects of suspended and dissolved solids in natural waters on chlorpyrifos bioavailability cannot be predicted.

4-14.0 Threatened and endangered species

Current lists of state and federally listed threatened and endangered plant and animal species in California were obtained from the California Department of Fish and Game web site (CDFG 2006a; b). The species *Oncorhynchus mykiss* (steelhead rainbow trout) is listed as federally threatened throughout California. The data set used to calculate the acute criterion includes a value for *O. mykiss* of 8.0 $\mu\text{g/L}$, indicating that the acute criterion of 10 ng/L should be protective of this species. *Oncorhynchus tshawytscha* (Chinook salmon) is listed as federally threatened or endangered, depending on season and location. The acute value for *O. tshawytscha* in the data set is 15.96 $\mu\text{g/L}$, so this species, too should be protected by the criterion. None of the other listed animals or plants is represented in the acute or chronic data set. However, some of the listed species are represented in the acute data set by members of the same family or genus and for these, the USEPA interspecies correlation estimation software (ICE v. 1.0, USEPA 2003b) was used to estimate toxicity values. Table 4.11 summarizes the results of the ICE analyses. The values in Table 4.11 range from 4.0 $\mu\text{g/L}$ for *Oncorhynchus clarki henshawi* (Lahontan cutthroat trout) to 171 $\mu\text{g/L}$ for *Ptychocheilus lucius* (Colorado squawfish). The value of 9.2 $\mu\text{g/L}$ estimated by ICE for *O. tshawytscha* is in agreement (within and order of magnitude) with the measured value of 15.96 $\mu\text{g/L}$ (calculated from data in Wheelock *et al.* 2005).

No plant data were rated relevant and reliable for criteria derivation, and none of the studies were of plants on the state or federal endangered, threatened, or rare species lists. As discussed in section 4-4.0, plants are relatively insensitive to chlorpyrifos and the calculated criteria should be protective. Based on the available data and estimated values for animals, there is no evidence that the calculated acute and chronic criteria will be under-protective of threatened and endangered species. The caveat is that this assessment is lacking data for the most sensitive species in the acute criterion data set, cladocerans and insects, but no data were found for effects of chlorpyrifos on federally endangered cladocerans or insects, or acceptable surrogates (i.e., in the same family).

4-15.0 Harmonization/coherence across media

The MacKay (2001) fugacity-based environmental equilibrium partitioning model, Level I, was used to estimate equilibrium concentrations of chlorpyrifos expected in sediment, biota, and air based on having 10.5 ng/L in water (a draft chronic criterion, very close to the final chronic criterion of 10 ng/L). To use this model, the organic carbon content of soil was set to zero so that no chlorpyrifos would partition into that compartment which is not in direct contact with water. Chlorpyrifos loading was adjusted by trial and error to a level that resulted in a final concentration in water of 10.5 ng/L. Default values were used for compartment volumes. The model was run several times over ranges of sediment and suspended sediment organic carbon content, and fish lipid content. Model inputs and outputs are summarized in Tables 4.12 and 4.13, respectively. The model used the K_{OW} to estimate a fish-water partition coefficient of 4,560, which is somewhat higher than the BCF of 1700 measured by Jarvinen *et al.* (1983). A log organic carbon-water partition coefficient (log K_{OC}) of 4.57 L/kg was also estimated. This log K_{OC} is within an order of magnitude of the geometric mean value of 4.06 determined in section 4-2.0. Since these estimated partition coefficients are somewhat higher than measured values, the model output will tend to overestimate the levels of chlorpyrifos in fish, sediment and suspended sediment.

The fish tissue concentration obtained from the worst case considered here (20% lipid content) was 191 ng/g. This fish tissue value is well below the dietary NOEC values of 25-46 µg/g for wildlife (section 4-3.0). There are no federal or state air or sediment quality standards for chlorpyrifos, nor is chlorpyrifos mentioned in the NOAA sediment quality guidelines (California Air Resources Board 2005, USEPA 2006b, c, NOAA 1999). Based on the MacKay fugacity model and available wildlife values, the chronic criterion of 10 ng/L should not cause problems in other environmental compartments.

4-16.0 Assumptions and limitations

The assumptions, limitations, and uncertainties involved in criteria generation should be available to inform environmental managers of the accuracy and confidence in criteria. Chapter 2 discusses these points for each section as different procedures were chosen, such as the list of assumptions associated with using an SSD, included in section 2-3.1.5.1, and reviews them in section 2-7.0. The different calculations of distributional estimates included in section 4-6.0 may be used to consider the uncertainty in the resulting acute criterion.

In this report for chlorpyrifos, the major limitation was in the chronic data set. Several taxa requirements were not met, including: the family Salmonidae, the benthic crustacean, and insect, which precluded the use of an SSD. Therefore, an ACR was used to derive the chronic criterion (see section 4-7.0). The final acute criterion was derived using the SSD procedure (see section 4-6.0)

4-17.0 Final chlorpyrifos criteria

The final criteria statement is:

Aquatic life in the Sacramento River and San Joaquin River basins should not be affected unacceptably if the four-day average concentration of chlorpyrifos does not exceed 10 ng/L more than once every three years on the average and if the one-hour average concentration does not exceed 10 ng/L more than once every three years on the average.

These criteria are lower than the USEPA chlorpyrifos acute and chronic freshwater criteria of 83 and 41 ng/L, respectively (USEPA 1986). They are also lower than current water quality objectives for the lower San Joaquin, Sacramento and Feather Rivers and the Sacramento-San Joaquin River Delta (CVRWQCB 2009). Acute and chronic objectives for both of these water bodies are 25 and 15 ng/L, respectively. These objectives are based on criteria derived by the California Department of Fish and Game (Siepmann & Finlayson 2000) using the USEPA (1985) methodology, but with a different data set than that used in USEPA (1986).

Table 2.4 of Chapter 2 of this report shows that when the same data set is used, the median 95th percentile acute values determined by the new methodology (23 ng/L) is close to that determined by the USEPA methodology (36 ng/L, Log-triangular distribution of SMAVs in Table 4.1). Therefore, the differences in the final acute criteria values are due to different data sets. The current data set includes values from 26 studies published after 1986, when the USEPA criteria were derived, and values from 9 studies published in or after 2000, when the Sacramento and San Joaquin River criteria were derived (Siepmann & Finlayson 2000). Chronic criteria in all three derivations were accomplished by applying an acute-to-chronic ratio (ACR) to the 5th percentile acute value. Thus, the differences in chronic criteria are due in part to the different acute data sets, and in part to the use of different ACRs. The USEPA (1986) derivation used an ACR of 4.064; Siepmann & Finlayson (2000) used 3.0, and this methodology used 2.2.

The USEPA (1986) acute criterion of 83 ng/L is higher than the lowest acute value of 35 ng/L for *Daphnia ambigua* in the current data set and is clearly not protective of the most sensitive species. The Sacramento and San Joaquin River acute objective of 25 ng/L (CVRWQCB 2009) is lower than the lowest acute value, but provides a margin of safety of just 1.4. The criterion of 10 µg/L derived by this methodology provides a larger, but not excessive, margin of safety (3.0) for the most sensitive species. The USEPA (1986) chronic criterion of 41 ng/L is approximately equal to the lowest chronic value of 40 ng/L for *Ceriodaphnia dubia* in the current data set. Clearly, there is potential for harm if the concentration of chlorpyrifos were at the level of the USEPA chronic criterion. The Sacramento and San Joaquin River chronic objective of 15 ng/L provides a margin of safety of 2.7, and the chronic criterion of 10 µg/L by this methodology provides a slightly larger margin of safety (3.8).

4-18.0 References

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Data Tables

Table 4.1 Final acute toxicity data set for chlorpyrifos. All studies were rated relevant and reliable (RR) and were conducted at standard temperature*. Values in bold are species mean acute values. S: static; SR: static renewal; FT: flow-through.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	Reference
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	96 h	25	Mortality	< 24 h	0.053	Bailey <i>et al.</i> (1997)
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	96 h	25	Mortality	< 24 h	0.055	Bailey <i>et al.</i> (1997)
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	SR	Meas	99.0%	96 h	24.6	Mortality	< 24 h	0.13	CDFG (1992f)
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	SR	Meas	99.0%	96 h	24.3	Mortality	< 24 h	0.08	CDFG (1992c)
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	SR	Meas	99.8%	96 h	24.6	Survival	< 24 h	0.0396	CDFG (1999)
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae						Geometric Mean		0.0654	
<i>Chironomus tentans</i>	Insect	Chironomidae	S	Meas	98.0%	96 h	21	Immobility	3-4th instar	0.16	Belden & Lydy (2006)
<i>Chironomus tentans</i>	Insect	Chironomidae	S	Meas	90.0%	96 h	21	Immobility	4th instar	0.17	Lydy & Austin (2005)
<i>Chironomus tentans</i>	Insect	Chironomidae	S	Meas	98.0%	96 h	20	Immobility + Mortality	4th instar	0.39	Belden & Lydy (2000)
<i>Chironomus tentans</i>	Insect	Chironomidae						Geometric Mean		0.220	
<i>Daphnia ambigua</i>	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	21	Immobility	Neonates	0.035	Harmon <i>et al.</i> (2003)

Table 4.1 Final acute toxicity data set for chlorpyrifos. All studies were rated relevant and reliable (RR) and were conducted at standard temperature*. Values in bold are species mean acute values. S: static; SR: static renewal; FT: flow-through.

Species	Common identifier	Family	Test type	Meas/Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	Reference
<i>Daphnia magna</i>	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	19.5	Mortality	< 24 h	1.0	Kersting & Van Wijngaarden (1992)
<i>Daphnia magna</i>	Cladoceran	Daphniidae	FT	Nom (most)	95.5%	48 h	18-21	Mortality	< 24 h	0.10	Burgess (1988)
<i>Daphnia magna</i>								Geometric Mean		0.32	
<i>Daphnia pulex</i>	Cladoceran	Daphniidae	S	Meas	Technical	48 h	20	Immobility	< 24 h	0.25	Van Der Hoeven & Gerritsen (1997)
<i>Hyaella azteca</i>	Amphipod	Hyaellidae	S	Meas	90.0%	96 h	20	Mortality	14-21 d	0.0427	Anderson & Lydy (2002)
<i>Hyaella azteca</i>	Amphipod	Hyaellidae	SR	Meas	98.1%	96 h	19	Mortality	14-21 d	0.138	Brown <i>et al.</i> (1997)
<i>Hyaella azteca</i>								Geometric Mean		.077	
<i>Ictalurus punctatus</i>	Channel catfish	Ictaluridae	FT	Meas	99.9%	96 h	17.3	Mortality	7.9 g	806	Phipps & Holcombe (1985)
<i>Lepomis macrochirus</i>	Bluegill	Centrarchidae	FT	Meas	99.9%	96 h	17.3	Mortality	0.8 g	10	Phipps & Holcombe (1985)
<i>Lepomis macrochirus</i>	Bluegill	Centrarchidae	FT	Meas	99.9%	96 h	22	Mortality	2.1 g	5.8	Bowman (1988)

Table 4.1 Final acute toxicity data set for chlorpyrifos. All studies were rated relevant and reliable (RR) and were conducted at standard temperature*. Values in bold are species mean acute values. S: static; SR: static renewal; FT: flow-through.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	Reference
<i>Lepomis macrochirus</i>								Geometric Mean		7.6	
<i>Neomysis mercedis</i>	Opossum shrimp	Mysidae	SR	Meas	99.0%	96 h	17.4	Mortality	< 5 d	0.15	CDFG (1992e)
<i>Neomysis mercedis</i>	Opossum shrimp	Mysidae	SR	Meas	99.0%	96 h	17.2	Mortality	< 5 d	0.16	CDFG (1992a)
<i>Neomysis mercedis</i>	Opossum shrimp	Mysidae	SR	Meas	99.0%	96 h	17.1	Mortality	< 5 d	0.14	CDFG (1992d)
<i>Neomysis mercedis</i>	Opossum shrimp	Mysidae						Geometric Mean		0.150	
<i>Oncorhynchus mykiss</i>	Rainbow trout	Salmonidae	FT	Meas	99.9%	96 h	12	Mortality	Juvenile	8.0	Holcombe <i>et al.</i> (1982)
<i>Oncorhynchus mykiss</i>	Rainbow trout	Salmonidae	FT	Meas	95.9%	96 h	12	Mortality	0.25 g	25.0	Bowman (1988)
<i>Oncorhynchus mykiss</i>								Geometric Mean		14	
<i>Oncorhynchus tshawytscha</i>	Chinook salmon	Salmonidae	SR	Meas	99.5%	96 h	14.8	Mortality	Juvenile	15.96	Wheelock <i>et al.</i> (2005)
<i>Orconectes immunis</i>	Crayfish	Cambaridae	FT	Meas	99.9%	96 h	17.3	Mortality	1.8 g	6	Phipps & Holcombe (1985)
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	FT	Meas	99.9%	96 h	25	Mortality	32 d	200	Geiger <i>et al.</i> (1988)

Table 4.1 Final acute toxicity data set for chlorpyrifos. All studies were rated relevant and reliable (RR) and were conducted at standard temperature*. Values in bold are species mean acute values. S: static; SR: static renewal; FT: flow-through.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	Reference
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	FT	Meas	99.9%	96 h	25	Mortality	31-32 d	203	Holcombe <i>et al.</i> (1982)
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	FT	Meas	98.7%	96 h	25	Mortality	Newly hatched	140	Jarvinen & Tanner (1982)
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae						Geometric Mean		178	
<i>Procloeon</i> sp.	Insect	Baetidae	SR	Meas	99%	48 h	21.3°C	Mortality	0.5-1.0 cm	0.1791	Anderson <i>et al.</i> (2006)
<i>Procloeon</i> sp.	Insect	Baetidae	SR	Meas	99%	48 h	21.3°C	Mortality	0.5-1.0 cm	0.0704	Anderson <i>et al.</i> (2006)
<i>Procloeon</i> sp.	Insect	Baetidae	SR	Meas	99%	48 h	21.3°C	Mortality	0.5-1.0 cm	0.0798	Anderson <i>et al.</i> (2006)
								Geometric Mean		0.100	
<i>Pungitius pungitius</i>	Stickleback	Gasterosteidae	FT	Meas	99.8%	96 h	19	Mortality	Adult	4.7	Van Wijngaarden <i>et al.</i> (1993)
<i>Simulium vittatum</i> IS-7	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	2nd & 3rd instar	0.06	Hyder <i>et al.</i> (2004)
<i>Xenopus laevis</i>	African clawed frog	Pipidae	SR	Nom	99.80%	96 h	24.7	Mortality	< 24 h	2410	El-Merhibi <i>et al.</i> (2004)

*Standard temperatures are particular for each species. See standard methods referenced in Tables 3.7 and 3.8 of the methodology.

Table 4.2 Acceptable acute data (relevant and reliable, rated RR) excluded in data reduction process.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	Reference	Reason for exclusion
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25 C	Mortality	< 24 h	0.101	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	0.079	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	72 h	25	Mortality	< 24 h	0.078	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25	Mortality	< 24 h	0.063	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	0.058	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	72 h	25	Mortality	< 24 h	0.058	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25	Mortality	< 24 h	0.095	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	0.066	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	25	Mortality	< 24 h	0.086	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Mortality	< 24 h	0.064	Bailey <i>et al.</i> (1997)	1
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Nom	99.8%	48 h	25.2	Mortality	< 24 h	0.05	El-Merhibi <i>et al.</i> (2004)	1, 2

Table 4.2 Acceptable acute data (relevant and reliable, rated RR) excluded in data reduction process.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	Reference	Reason for exclusion
<i>Ceriodaphnia dubia</i>	Cladoceran	Daphniidae	S	Meas	99.0%	48 h	25	Immobilization	Neonates	0.056	Harmon <i>et al.</i> (2003)	1
<i>Chironomus tentans</i>	Insect	Chironomidae	S	Nom	95.0%	96 h	23	Mortality/Immobilization	3rd instar	0.47	Ankley & Collyard (1995)	2
<i>Chironomus tentans</i>	Insect	Chironomidae	S	Nom	99.0%	96 h	20	Immobilization	4th instar	0.58	Pape-Lindstrom & Lydy (1997)	2
<i>Chironomus tentans</i>	Insect	Chironomidae	S	Nom	99.0%	96 h	20	Immobilization	4th instar	0.75	Pape-Lindstrom & Lydy (1997)	2
<i>Chironomus tentans</i>	Insect	Chironomidae	S	Nom	99.0%	96 h	20	Immobilization	4th instar	0.51	Pape-Lindstrom & Lydy (1997)	2
<i>Daphnia magna</i>	Cladoceran	Daphniidae	S	Meas	99.0%	24 h	19.5	Mortality	< 24 h	3.7	Kersting & Van Wijngaarden (1992)	3
<i>Daphnia pulex</i>	Cladoceran	Daphniidae	S	Meas	Technical	48 h	19.5	Mortality	< 24 h	0.3	Van Der Hoeven & Gerritsen (1997)	4
<i>Daphnia pulex</i>	Cladoceran	Daphniidae	S	Meas	Technical	24 h	20	Immobilization	< 24 h	0.42	Van Der Hoeven & Gerritsen (1997)	3
<i>Hyaella azteca</i>	Amphipod	Hyalellidae	S	Nom	95.0%	96 h	23	Mortality/Immobilization	7-14 d	0.04	Ankley & Collyard (1995)	2

Table 4.2 Acceptable acute data (relevant and reliable, rated RR) excluded in data reduction process.

Species	Common identifier	Family	Test type	Meas/Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	Reference	Reason for exclusion
<i>Oncorhynchus mykiss</i>	Rainbow trout	Salmonidae	FT	Meas	99.9%	48 h	25	Mortality	Juvenile	11.4	Holcombe <i>et al.</i> (1982)	1
<i>Oncorhynchus mykiss</i>	Rainbow trout	Salmonidae	FT	Meas	99.9%	72 h	25	Mortality	Juvenile	8.0	Holcombe <i>et al.</i> (1982)	1
<i>Oncorhynchus mykiss</i>	Rainbow trout	Salmonidae	FT	Meas	99.9%	96 h	17.3	Mortality	3.0 g	9	Phipps & Holcombe (1985)	5
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	SR	Meas	98.0%	48 h	21	Mobility	< 24 h	200	Belden & Lydy (2006)	1, 7
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	FT	Meas	99.9%	24 h	25	Mortality	31-32 d	320	Holcombe <i>et al.</i> (1982)	1
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	FT	Meas	99.9%	48 h	25	Mortality	31-32 d	248	Holcombe <i>et al.</i> (1982)	1
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	FT	Meas	99.9%	72 h	25	Mortality	31-32 d	220	Holcombe <i>et al.</i> (1982)	1
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	S	Meas	98.7%	96 h	25	Mortality	Newly hatched	150-170	Jarvinen & Tanner (1982)	7
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	FT	Meas	99.9%	96 h	16	Mortality	44 d	506	Geiger <i>et al.</i> (1988)	5
<i>Pimephales promelas</i>	Fathead minnow	Cyprinidae	FT	Meas	99.9%	96 h	17.3	Mortality	0.5 g	542	Phipps & Holcombe (1985)	5
<i>Pungitius pungitius</i>	Stickleback	Gasterosteidae	FT	Meas	99.8%	48 h	19	Mortality	Adult	5.7	Van Wijngaarden <i>et al.</i> (1993)	1

Table 4.2 Acceptable acute data (relevant and reliable, rated RR) excluded in data reduction process.

Species	Common identifier	Family	Test type	Meas/ Nom	Chemical grade	Duration	Temp (°C)	Endpoint	Age/size	LC/EC₅₀ (µg/L)	Reference	Reason for exclusion
<i>Simulium vittatum</i> IS-7	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	4th & 5th instar	0.11	Hyder <i>et al.</i> (2004)	6
<i>Simulium vittatum</i> IS-7	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	6th & 7th instar	0.68	Hyder <i>et al.</i> (2004)	6
<i>Simulium vittatum</i> III-1	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	6th & 7th instar	0.91	Hyder <i>et al.</i> (2004)	6
<i>Simulium vittatum</i> III-1	Insect	Simuliidae	S	Meas	98.0%	24 h	19	Mortality	4th & 5th instar	0.13	Hyder <i>et al.</i> (2004)	6

1. 96-h result available
2. Test with measured concentrations available
3. 48-h result available
4. More sensitive endpoint available
5. Non-standard temperature
6. More sensitive lifestage available
7. Flow-through test available

Table 4.3 Final chronic toxicity data set for chlorpyrifos. All studies were rated relevant and reliable (RR) and were conducted at standard temperature*. Values in bold are species mean chronic values. SR: static renewal; FT: flow-through.

Species	Common identifier	Test type	Meas/ Nom	Chemical	Duration	Temp (°C)	Endpoint	Age/size	NOEC (ug/L)	LOEC (ug/L)	MATC (ug/L)	Reference
<i>Ceriodaphnia dubia</i>	Cladoceran	SR	Meas	99.8%	7 d	24.6	Mortality	< 24 h	0.029	0.054	0.0396	CDFG (1999)
<i>Ceriodaphnia dubia</i>	Cladoceran	SR	Meas	99.8%	7 d	24.6	Reproduction	< 24 h	0.029	0.054	0.0396	CDFG (1999)
<i>Ceriodaphnia dubia</i>	Cladoceran						Geometric Mean		0.029	0.054	0.0396	
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	60 d	24.3-25.9	Growth	< 24 h	0.63	1.21	0.87	Jarvinen <i>et al.</i> (1983)
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	32 d	23.5-26.0	Weight	Newly hatched	1.6	3.2	2.3	Jarvinen & Tanner (1982)
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	99.7%	25 & 32 d	25.0-25.5	F ₀ & F ₁ Mortality	< 24 h	0.568	1.093	0.788	Mayes <i>et al.</i> 1993
<i>Pimephales promelas</i>	Fathead minnow						Geometric Mean		0.83	1.62	1.16	
<i>Neomysis mercedis</i>	Opossum shrimp	SR	Meas	99.0%	96 h	17	Mortality	< 5 d	0.001 [†]			CDFG (1992a)
<i>Neomysis mercedis</i>	Opossum shrimp	SR	Meas	99.0%	96 h	17	Mortality	< 5 d	0.001 [†]			CDFG (1992e)
							Geometric Mean		0.001[†]			

*Standard temperatures are particular for each species. See standard methods referenced in Tables 3.7 and 3.8 of the methodology.

[†]Chronic values for *Neomysis mercedis* were estimated from acute data.

Table 4.4 Calculation of the final acute-to-chronic ratio. Values in bold were used in the calculation.

Species	Common identifier	LC ₅₀ (µg/L)	Reference	Chronic Endpoint	MATC (µg/L)	Reference	ACR (LC ₅₀ /MATC)
<i>Ceriodaphnia dubia</i>	Cladoceran	0.0396	CDFG (1999)	Mortality	0.040	CDFG (1999)	1.0
<i>Ceriodaphnia dubia</i>	Cladoceran	0.0396	CDFG (1999)	Reproduction	0.040	CDFG (1999)	1.0
<i>Ceriodaphnia dubia</i>	Cladoceran					Species Mean ACR	1.0
<i>Pimephales promelas</i>	Fathead minnow	140	Jarvinen & Tanner (1982)	Weight	2.3	Jarvinen & Tanner (1982)	61 ^a
<i>Leuresthes tenuis</i> ^b	California grunion	1.0	Borthwick <i>et al.</i> (1985)	Growth	0.2	Goodman <i>et al.</i> (1985)	5.0
						Final ACR	2.2

^a Excluded; > 10x the ACR for cladocerans whose species mean acute value is nearest the 5th percentile value of 0.026 µg/L.

^b Saltwater species included in ACR calculation; study rated relevant and reliable in every other respect (see Table 4.6).

Table 4.5 Acceptable chronic data excluded in data reduction process.

Species	Common identifier	Test type	Meas /Nom	Chemical purity	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference	Reason for exclusion
<i>Chironomus tentans</i>	Midge	FT	Meas	99.0%	10 d	20	Mortality	3rd instar	0.070 (10-d LC ₅₀)	-----	-----	Ankley <i>et al.</i> (1994)	1
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	32 d	23.5-26.0	Mortality	Newly hatched	3.2	5.7	4.3	Jarvinen & Tanner (1982)	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	Growth	< 24 h	1.21	2.68	1.8	Jarvinen <i>et al.</i> (1983)	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Growth	< 24 h	1.21	2.68	1.8	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	200 d	24.3-25.9	Growth	< 24 h	2.68	> 2.68	-----	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Total egg production	< 24 h	0.27	0.63	0.41	Jarvinen <i>et al.</i> 1983	3
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Maturation	< 24 h	< 1.21	0.12	-----	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Mean spawns per spawning pair	< 24 h	1.21	2.68	1.8	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	136 d	24.3-25.9	Embryo hatchability	< 24 h	1.21	2.68	1.8	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation survival	< 24 h	2.68	> 2.68	-----	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation normal	< 24 h	1.21	2.68	1.8	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation weight	< 24 h	0.63	1.21	0.87	Jarvinen <i>et al.</i> 1983	2

Table 4.5 Acceptable chronic data excluded in data reduction process.

Species	Common identifier	Test type	Meas /Nom	Chemical purity	Duration	Temp (°C)	Endpoint	Age/size	NOEC (µg/L)	LOEC (µg/L)	MATC (µg/L)	Reference	Reason for exclusion
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation length	< 24 h	0.63	1.21	0.87	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	2nd generation biomass	< 24 h	< 0.12	0.12	-----	Jarvinen <i>et al.</i> 1983	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	32 d	24.3-25.9	Weight	Newly hatched	1.6	3.2	2.3	Jarvinen & Tanner (1982)	2
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	30 d	24.3-25.9	Mortality	< 24 h	1.21	2.68	1.8	Jarvinen <i>et al.</i> 1983	2

1. No NOEC, LOEC or MATC determined
2. More sensitive endpoint available from same test
3. Large response at NOEC

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Anguilla anguilla</i>	European eel	S	Nom	97.0%	24 h @ 20°C	Mortality	20-30 g	1290	-----	Ferrando <i>et al.</i> (1991)	LL/ 4, 7
<i>Anguilla anguilla</i>	European eel	S	Nom	97.0%	48 h @ 20°C	Mortality	20-30 g	690	-----	Ferrando <i>et al.</i> 1991	LL/ 4, 7
<i>Anguilla anguilla</i>	European eel	S	Nom	97.0%	72 h @ 20°C	Mortality	20-30 g	590	-----	Ferrando <i>et al.</i> 1991	LL/ 4, 7
<i>Anguilla anguilla</i>	European eel	S	Nom	97.0%	96 h @ 20°C	Mortality	20-30 g	540	-----	Ferrando <i>et al.</i> 1991	LL/ 4, 7
<i>Anisus vortex</i>	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Mortality	7.2 mm	> 94	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 6, 7
<i>Anisus vortex</i>	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Immobility	7.2 mm	> 94	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 6, 7
<i>Aplexa hypnorum</i>	Snail	FT	Meas	98.7%	96 h @ 17.3°C	Mortality	Adult	> 806	-----	Phipps & Holcombe (1985)	LR/ 6
<i>Bithynia tentaculata</i>	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Mortality	10.5 mm	> 94	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 6, 7
<i>Bithynia tentaculata</i>	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Immobility	10.5 mm	> 94	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 6, 7

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Brachionus calyciflorus</i>	Rotifer	S	Nom	NR	48 h @ 25°C	Intrinsic rate of increase (r)	< 2 h	0.36	0.27	Snell & Moffat (1992)	LL/ 1, 7
<i>Brachionus calyciflorus</i>	Rotifer	S	Nom	NR	24 h @ 25°C	Mortality	0-2 h	12,000	-----	Snell <i>et al.</i> (1991)	LL/ 1, 7
<i>Carassius auratus</i>	Goldfish	FT	Meas	99.9%	96 h @ 17.3°C	Mortality	10.7 g	> 806	-----	Phipps & Holcombe (1985)	LR/ 6
<i>Ceriodaphnia dubia</i>	Cladoceran	SR	Meas	99.0%	96 h @ 24.5°C	Mortality	< 24 h	0.118	0.118	CDFG (1992b)	LR/ 4
<i>Chironomus tentans</i>	Insect	S	Nom	99.5%	48 h @ 25°C	Immobility	4 th instar	0.49	-----	Jin-Clark <i>et al.</i> (2002)	RL/ 7
<i>Chironomus tentans</i>	Insect	SR	Nom	99.5%	29 d @ 25°C	Mortality	Newly hatched	-----	-----	Rakotondravelo <i>et al.</i> (2006)	LL/ 6, 7
<i>Chironomus tentans</i>	Insect	SR	Nom	99.5%	29 d @ 25°C	Growth	Newly hatched	-----	-----	Rakotondravelo <i>et al.</i> (2006)	LL/ 6, 7
<i>Claassenia sabulosa</i>	Insect	S	Nom	97%	24 h @ 15°C	Mortality	2 nd year class	8.2	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Claassenia sabulosa</i>	Insect	S	Nom	97%	96 h @ 15°C	Mortality	2 nd year class	0.57	-----	Mayer & Ellersieck (1986)	LL/ 4, 7

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Cloeon dipterum</i>	Insect	FT	Meas	48%	48 h @ 18°C	Mortality	Naiads	1.0	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 1, 7
<i>Cloeon dipterum</i>	Insect	FT	Meas	48%	96 h @ 18°C	Mortality	Naiads	0.3	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 1, 7
<i>Cyprinodon variegatus</i>	Sheepshead minnow	FT	Meas	92%	28 d @ 30°C	Mortality	Embryo	-----	-----	Cripe <i>et al.</i> (1986)	LR/ 5, 6
<i>Cyprinodon variegatus</i>	Sheepshead minnow	FT	Meas	92%	28 d @ 30°C	Growth, wet weight	Embryo	-----	2.26	Cripe <i>et al.</i> (1986)	LR/ 5
<i>Cyprinodon variegatus</i>	Sheepshead minnow	FT	Meas	92%	28 d @ 30°C	Growth, dry weight	Embryo	-----	4.72	Cripe <i>et al.</i> (1986)	LR/ 5
<i>Cyprinodon variegatus</i>	Sheepshead minnow	FT	Meas	92%	96 h @ 31.4°C	Mortality	Not Reported	136	-----	Schimmel <i>et al.</i> (1983)	LL/ 5
<i>Daphnia magna</i>	Cladoceran	S	Meas	99%	24 h @ temperature not reported	AChE inhibition (50% at LC ₅₀)	Juvenile	0.42 (IC ₅₀)	-----	Barata <i>et al.</i> (2004)	LL/ 4,7
<i>Daphnia magna</i>	Cladoceran	SR	Nom	99.0%	21 d @ 19.5°C	Survival	< 24 h	-----	0.17	Kersting & Van Wijngaarden (1992)	RL/ 7
<i>Daphnia magna</i>	Cladoceran	SR	Nom	99.0%	21 d @ 19.5°C	Reproduction	< 24 h	-----	0.17	Kersting & Van Wijngaarden (1992)	RL/ 7

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Daphnia magna</i>	Cladoceran	S	Nom	Analytical	48 h @ 21°C	Immobility	< 24 h	0.19	-----	Kikuchi <i>et al.</i> (2000)	RL/ 7
<i>Daphnia magna</i>	Cladoceran	S	Nom	Analytical	48 h @ 25°C	Mortality	1 st instar	1.7	-----	McCarty (1977)	RL/ 7
<i>Daphnia magna</i>	Cladoceran	S	Meas	44.9%	48 h @ 20°C	Immobility	< 24 h	0.6	-----	Moore <i>et al.</i> (1998)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	S	Meas	45.0%	48 h @ 20°C	Mortality/ Immobility	< 24 h	0.21	-----	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	10 d @ 20°C	Mortality/ Immobility	< 24 h	0.19	-----	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	17 d @ 20°C	Reproduction	< 24 h	-----	0.14	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	6 d @ 20°C	Mortality/ Immobility	< 24 h	0.39	-----	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	6 d @ 20°C	Length	< 24 h	-----	0.48	Van Der Hoeven & Gerritsen (1997)	LR/ 1

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	8 d @ 20°C	Mortality/ Immobility	7-8 d	0.28	-----	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	8 d @ 20°C	Reproduction	7-8 d	-----	0.28	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	6 d @ 20°C	Mortality/ Immobility	9-10 d	0.42	-----	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	6 d @ 20°C	Reproduction	9-10 d	-----	-----	Van Der Hoeven & Gerritsen (1997)	LR/ 1, 6
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	28 d @ 20°C	Population size	Mixed ages	-----	0.116	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Daphnia pulex</i>	Cladoceran	SR	Meas	45.0%	28 d @ 12-23°C	Population size	Mixed ages	-----	0.202	Van Der Hoeven & Gerritsen (1997)	LR/ 1
<i>Fundulus similis</i>	Longnose killifish	FT	Meas	92.0%	96 h @ 30°C	Mortality	Not Reported	4.1	-----	Schimmel <i>et al.</i> (1983)	LL/ 5, 7
<i>Gammarus fasciatus</i>	Amphipod	S	Nom	Technical	96 h @ 21°C	Mortality	30-50 mg; 7-11 mg	0.32	-----	Sanders (1972)	LL/ 4, 7

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Gasterosteus aculeatus</i>	Stickleback	FT	Meas	48.0%	48 h @ 21°C	Mortality	1-2 yr	13.4	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 1, 7
<i>Gasterosteus aculeatus</i>	Stickleback	FT	Meas	48.0%	96 h @ 21°C	Mortality	1-2 yr	8.5	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 1, 7
<i>Hyaella azteca</i>	Amphipod	S	Meas	44.9%	48 h @ 20°C	Immobility	2-3 wk	0.1	-----	Moore <i>et al.</i> (1998)	LR/ 1
<i>Lepomis macrochirus</i>	Bluegill	S	Nom	97%	24 h @ 18°C	Mortality	0.6 g	> 10	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Lepomis macrochirus</i>	Bluegill	S	Nom	97%	96 h @ 18°C	Mortality	0.6 g	2.4	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Lepomis macrochirus</i>	Bluegill	S	Nom	97%	96 h @ 13°C	Mortality	0.5 g	4.2	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Lepomis macrochirus</i>	Bluegill	S	Nom	97%	96 h @ 18°C	Mortality	0.5 g	1.8	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Lepomis macrochirus</i>	Bluegill	S	Nom	97%	96 h @ 24°C	Mortality	0.5 g	2.5	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Lepomis macrochirus</i>	Bluegill	S	Nom	97%	96 h @ 29°C	Mortality	0.5 g	1.7	-----	Mayer & Ellersieck (1986)	LL/ 4, 7

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Leuresthes tenuis</i>	California grunion	FT	Meas	92%	96 h @ 25°C	Mortality	7 d	1.0	-----	Borthwick <i>et al.</i> (1985)	LR/ 5
<i>Leuresthes tenuis</i>	California grunion	FT	Meas	92%	35 d @ 23-26°C	Embryo survival	Embryo	-----	-----	Goodman <i>et al.</i> (1985)	LR/ 5
<i>Leuresthes tenuis</i>	California grunion	FT	Meas	92%	35 d @ 23-26°C	Fry survival	Embryo	-----	0.43	Goodman <i>et al.</i> (1985)	LR/ 5
<i>Leuresthes tenuis</i>	California grunion	FT	Meas	92%	35 d @ 23-26°C	Embryo + fry survival	Embryo	-----	0.94	Goodman <i>et al.</i> (1985)	LR/ 5
<i>Leuresthes tenuis</i>	California grunion	FT	Meas	92%	35 d @ 23-26°C	Embryo growth	Embryo	-----	0.2	Goodman <i>et al.</i> (1985)	LR/ 5
<i>Leuresthes tenuis</i>	California grunion	FT	Meas	92%	26 d @ 23-26°C	Fry survival	Fry	-----	0.9	Goodman <i>et al.</i> (1985)	LR/ 5
<i>Leuresthes tenuis</i>	California grunion	FT	Meas	92%	26 d @ 23-26°C	Fry growth	Fry	-----	0.42	Goodman <i>et al.</i> (1985)	LR/ 5
<i>Lumbriculus variegatus</i>	Oligochaete	S	Nom	≥ 95%	96 h @ 23°C	Mortality/ Immobility	Mixed ages	-----	-----	Ankley & Collyard (1995)	LL/ 6, 7
<i>Lymnaea stagnalis</i>	Gastropod	FT	Meas	99.8%	96 h @ 20°C	Mortality/ Immobility	22.4 mm	> 94	-----	Van Wijngaarden <i>et al.</i> (1993)	LR/ 6

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Menidia menidia</i>	Atlantic silverside	FT	Meas	92.0%	96 h @ 25°C	Mortality	0 d	0.5	-----	Borthwick <i>et al.</i> (1985)	LR/ 5
<i>Menidia menidia</i>	Atlantic silverside	FT	Meas	92.0%	96 h @ 27.5°C	Mortality	Not Reported	1.7	-----	Schimmel <i>et al.</i> (1983)	LL/ 5, 7
<i>Menidia peninsulae</i>	Gulf silverside	FT	Meas	92.0%	96 h @ 25°C	Mortality	14 d	0.4	-----	Borthwick <i>et al.</i> (1985)	LR/ 5
<i>Minutocellus polymorphus</i>	Marine diatom	S	Meas	97%	48 h @ 20°C	Population density	Not Reported	240	-----	Walsh <i>et al.</i> (1988)	LL/ 4, 5, 7
<i>Mugil cephalus</i>	Striped mullet	FT	Meas	92.0%	96 h @ 24.8°C	Mortality	Not Reported	5.4	-----	Schimmel <i>et al.</i> (1983)	LL/ 5, 7
<i>Mysidopsis bahia</i>	Mysid	FT	Meas	95.0%	96 h @ 24.5°C	Mortality/ Immobility	< 24 h	5.4	-----	Surprenant (1989)	LR/ 5
<i>Mysidopsis bahia</i>	Mysid	FT	Meas	99.7%	35 d @ 27°C	Mortality/ Immobility	< 24 h	-----	0.0068	Sved <i>et al.</i> (1993)	LR/ 4, 5
<i>Oncorhynchus kisutch</i>	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	Enzyme activity	4-5 mo	-----	-----	Sandahl <i>et al.</i> (2005)	LR/ 2
<i>Oncorhynchus kisutch</i>	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	Spontaneous swimming rate	4-5 mo	-----	-----	Sandahl <i>et al.</i> (2005)	LR/ 2

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Oncorhynchus kisutch</i>	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	Feeding swimming rate	4-5 mo	-----	0.85	Sandahl <i>et al.</i> (2005)	LR/ 2
<i>Oncorhynchus kisutch</i>	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	First feeding strike	4-5 mo	-----	2.1	Sandahl <i>et al.</i> (2005)	LR/ 2
<i>Oncorhynchus kisutch</i>	Coho salmon	SR	Meas	99.3%	96 h @ 11-13°C	Total feeding strikes	4-5 mo	-----	2.1	Sandahl <i>et al.</i> (2005)	LR/ 2
<i>Oncorhynchus mykiss</i>	Rainbow trout	S	Meas	97.0%	24 h @ 2.0°C	Mortality	1.4 g	550	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Oncorhynchus mykiss</i>	Rainbow trout	S	Meas	97.0%	96 h @ 2.0°C	Mortality	1.4 g	51	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Oncorhynchus mykiss</i>	Rainbow trout	S	Meas	97.0%	24 h @ 7.0°C	Mortality	1.4 g	110	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Oncorhynchus mykiss</i>	Rainbow trout	S	Meas	97.0%	96 h @ 7.0°C	Mortality	1.4 g	15	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Oncorhynchus mykiss</i>	Rainbow trout	S	Meas	97.0%	96 h @ 13°C	Mortality	1.4 g	7.1	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Oncorhynchus mykiss</i>	Rainbow trout	S	Meas	97.0%	24 h @ 18°C	Mortality	1.4 g	15	-----	Mayer & Ellersieck (1986)	LL/ 4, 7

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Oncorhynchus mykiss</i>	Rainbow trout	S	Meas	97.0%	24 h @ 13°C	Mortality	1.4 g	53	-----	Mayer & Ellersieck (1986)	LL/ 4, 7
<i>Oryzias latipes</i>	Medaka	SR	Meas	99.0%	24 h @ 25°C	Mortality	30 d	300	-----	Rice <i>et al.</i> (1997)	LR/ 3
<i>Oryzias latipes</i>	Medaka	SR	Meas	99.0%	48 h @ 25°C	Mortality	30 d	250	-----	Rice <i>et al.</i> (1997)	LR/ 3
<i>Pimephales promelas</i>	Fathead minnow	S	Meas	10.6%	96 h @ 23.5-26.0°C	Mortality	Newly hatched	130-280	-----	Jarvinen & Tanner (1982)	LR/ 1
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	10.6%	96 h @ 23.5-26.0°C	Mortality	Newly hatched	120.0	-----	Jarvinen & Tanner (1982)	LR/ 1
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	10.6%	32 d @ 23.5-26.0°C	Mortality	Newly hatched	-----	3.2	Jarvinen & Tanner (1982)	LR/ 1
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	10.6%	32 d @ 23.5-26.0°C	Weight	Newly hatched	-----	3.2	Jarvinen & Tanner (1982)	LR/ 1
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.70%	30 d @ 24.3-25.9°C	Mortality	< 24 h	-----	0.87	Jarvinen <i>et al.</i> (1983)	LR/ 4
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	60 d @ 24.3-25.9°C	AChE inhibition (21-41% at LOEC)	< 24 h	-----	-----	Jarvinen <i>et al.</i> (1983)	LR/ 2, 6

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Pimephales promelas</i>	Fathead minnow	FT	Meas	98.7%	136 d @ 24.3-25.9°C	Mean eggs per spawn	< 24 h	-----	0.87	Jarvinen <i>et al.</i> (1983)	LR/ 6
<i>Pimephales promelas</i>	Fathead minnow	S	Meas	10.6%	96 h @ 24.6-25.4°C	Mortality	< 24 h	122.2	-----	Jarvinen <i>et al.</i> (1988)	LR/ 1, 4, 7
<i>Pimephales promelas</i>	Fathead minnow	S	Meas	10.6%	28-30 d @ 24.6-25.4°C	Deformities	< 24 h	-----	1.65	Jarvinen <i>et al.</i> (1988)	LR/ 1
<i>Pimephales promelas</i>	Fathead minnow	S	Meas	44.9%	48 h @ 20°C	Immobility	< 24 h	162.7	-----	Moore <i>et al.</i> (1998)	LR/ 1
<i>Pimephales promelas</i>	Fathead minnow	SR	Meas	NR	7 d @ 25°C	Growth	< 24 h	-----	5.2	Norberg & Mount (1985)	LL/ 1, 7
<i>Pimephales promelas</i>	Fathead minnow	SR	Meas	24.7%	96 h @ 25°C	Mortality	< 24 h	381	-----	Sherrard <i>et al.</i> (2002)	LL/ 1, 4, 7
<i>Pimephales promelas</i>	Fathead minnow	SR	Meas	24.7%	10 d @ 25°C	Mortality	< 24 h	150	-----	Sherrard <i>et al.</i> (2002)	LL/ 1, 4, 7
<i>Pimephales promelas</i>	Fathead minnow	SR	Meas	24.7%	96 h @ 25°C	Growth	< 24 h	-----	112	Sherrard <i>et al.</i> (2002)	LL/ 1, 4, 7
<i>Pimephales promelas</i>	Fathead minnow	SR	Meas	24.7%	10 d @ 25°C	Growth	< 24 h	-----	61	Sherrard <i>et al.</i> (2002)	LL/ 1, 4, 7

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Procambarus clarkii</i>	Crayfish	S	Nom	99.8%	24 h @ 22°C	Mortality	15-30 g	37	-----	Cebrián <i>et al.</i> (1992)	RL/ 7
<i>Procambarus clarkii</i>	Crayfish	S	Nom	99.8%	48 h @ 22°C	Mortality	15-30 g	23	-----	Cebrián <i>et al.</i> (1992)	RL/ 7
<i>Procambarus clarkii</i>	Crayfish	S	Nom	99.8%	72 h @ 22°C	Mortality	15-30 g	22	-----	Cebrián <i>et al.</i> (1992)	RL/ 7
<i>Procambarus clarkii</i>	Crayfish	S	Nom	99.8%	96 h @ 22°C	Mortality	15-30 g	21	-----	Cebrián <i>et al.</i> (1992)	RL/ 7
<i>Pteronarcys californica</i>	Insect	S	Nom	97%	24 h @ 15°C	Mortality	2nd year class	50	-----	Mayer & Ellersieck (1986)	RL/ 4, 7
<i>Rana catesbeiana</i>	Bullfrog	SR	Nom	98.8%	96 h @ 22°C	Lethargy, loss of equilibrium, ascites, swimming at the surface	Larvae (5.7g post test)	552	-----	Henry & Kirk 2001	LR/ 2
<i>Simocephalus vetulus</i>	Cladoceran	SR	Meas	48.0%	48 h @ 18°C	Mortality	Juvenile-adult	0.8	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 1, 7
<i>Simocephalus vetulus</i>	Cladoceran	SR	Meas	48.0%	96 h @ 18°C	Mortality	Juvenile-adult	0.5	-----	Van Wijngaarden <i>et al.</i> (1993)	LL/ 1, 7
<i>Skeletonema costatum</i>	Marine diatom	S	Meas	97%	72 h @ 20°C	Population density	Not Reported	640	-----	Walsh <i>et al.</i> (1988)	

Table 4.6 Studies excluded from criteria derivation (rated RL, LR, or LL; L = less relevant or less reliable). S = static, SR = static renewal, FT = flow-through

Species (Family)	Common identifier	Test type	Meas/ Nom	Chemical grade	Duration/Temp	Endpoint	Age/size	LC/EC ₅₀ (µg/L)	MATC (µg/L)	Reference	Rating/ Reason for rating
<i>Stizostedion vitreum</i>	Walleye	S	Meas	99.6%	48 h @ 13.9-22.2°C	Mortality	Various	12-225	-----	Phillips <i>et al.</i> 2002	LL/ 4, 7
<i>Xenopus laevis</i>	African clawed frog	SR	Nom	99.8%	10 d @ 24.7°C	Mortality	< 24 h	-----	28	El-Merhibi <i>et al.</i> (2004)	RL/ 7
<i>Xenopus laevis</i>	African clawed frog	SR	Nom	99.8%	10 d @ 24.7°C	Malformation	< 24 h	-----	28	El-Merhibi <i>et al.</i> (2004)	RL/ 7
<i>Xenopus laevis</i>	African clawed frog	SR	Nom	99.8%	10 d @ 24.7°C	AChE inhibition	< 24 h	-----	7.1	El-Merhibi <i>et al.</i> (2004)	RL/ 7

1. Chemical grade
2. Endpoint not linked to population effects
3. Family not in N. America
4. Control description/response
5. Not freshwater
6. No toxicity value calculated
7. Low reliability score

Table 4.7 Acceptable multispecies field, semi-field, laboratory, microcosm, and mesocosm studies; R = reliable; L = less reliable.

Reference	Habitat	Rating
Brock <i>et al.</i> (1992a)	Laboratory model ecosystem	L
Brock <i>et al.</i> (1992b)	Laboratory model ecosystem	L
Brock <i>et al.</i> (1993)	Laboratory model ecosystem	R
Cuppen <i>et al.</i> (1995)	Laboratory microcosm	L
Eaton <i>et al.</i> (1985)	Outdoor stream	L
Giddings <i>et al.</i> (1997)	Outdoor pond	R
Kersting & Van Den Brink (1997)	Outdoor ditch	L
Kersting & Van Wijngaarden (1992)	Laboratory microcosm	L
Macek <i>et al.</i> (1972)	Outdoor pond	R
Pusey <i>et al.</i> (1994)	Outdoor stream	L
Rawn <i>et al.</i> (1978)	Outdoor pond	R
Siefert (1984)	Outdoor pond	R
Van Breukelen & Brock (1993)	Laboratory microcosm	L
Van Den Brink <i>et al.</i> (1995)	Laboratory microcosm	L
Van Den Brink <i>et al.</i> (1996)	Outdoor ditch	L
Van Donk <i>et al.</i> (1995)	Laboratory microcosm	L
Van Wijngaarden & Leeuwangh (1989)	Outdoor pond	L
Van Wijngaarden (1993)	Laboratory microcosm	R
	Outdoor pond	R
	Outdoor ditch	R
Van Wijngaarden <i>et al.</i> (1996)	Outdoor ditch	R
Van Wijngaarden <i>et al.</i> (2005)	Laboratory microcosm	L
Ward <i>et al.</i> (1995)	Artificial stream	L

Table 4.8 *Neomysis mercedis* raw acute data from CDFG (1992a) used for estimation of chronic toxicity using ACE (v. 2.0).

Chlorpyrifos (µg/L)	Time (h)	Total exposed	Total responding
0	24	20	1
0.06	24	20	0
0.14	24	20	0
0.30	24	20	1
0.61	24	20	7
1.30	24	20	20
0	48	20	1
0.06	48	20	0
0.14	48	20	0
0.30	48	20	11
0.61	48	20	19
1.30	48	20	20
0	72	20	1
0.06	72	20	0
0.14	72	20	2
0.30	72	20	19
0.61	72	20	20
1.30	72	20	20
0	96	20	1
0.06	96	20	0
0.14	96	20	7
0.30	96	20	20
0.61	96	20	20
1.30	96	20	20

Table 4.9 *Neomysis mercedis* raw acute data from CDFG (1992e) used for estimation of chronic toxicity using ACE (v. 2.0).

Chlorpyrifos (µg/L)	Time (h)	Total exposed	Total responding
0	24	10	0
0.04	24	10	0
0.09	24	10	0
0.18	24	10	0
0.36	24	10	0
0.75	24	10	3
0	48	10	0
0.04	48	10	0
0.09	48	10	0
0.18	48	10	0
0.36	48	10	8
0.75	48	10	10
0	72	10	0
0.04	72	10	0
0.09	72	10	0
0.18	72	10	5
0.36	72	10	10
0.75	72	10	10
0	96	10	0
0.04	96	10	0
0.09	96	10	0
0.18	96	10	7
0.36	96	10	10
0.75	96	10	10

Table 4.10 Synergistic interactions between chlorpyrifos and other pesticides.

Species	Pesticide 1	Synergist (concentration)	SR (K) ¹	Reference
<i>Pimephales promelas</i>	Esfenvalerate	Chlorpyrifos (7 µg/L)	1.29	Belden & Lydy 2006
<i>Chironomus tentans</i>	Chlorpyrifos	Atrazine (200 µg/L)	1.75	Jin-Clark <i>et al.</i> 2002
<i>Chironomus tentans</i>	Chlorpyrifos	Cyanazine (200 µg/L)	2.23	Jin-Clark <i>et al.</i> 2002
<i>Chironomus tentans</i>	Chlorpyrifos	Cyanazine (200 µg/L)	1.7	Lydy & Austin 2004
<i>Chironomus tentans</i>	Chlorpyrifos	Simazine (200 µg/L)	1.8	Lydy & Austin 2004
<i>Chironomus tentans</i>	Chlorpyrifos	Hexazione (200 µg/L)	1.6	Lydy & Austin 2004
<i>Chironomus tentans</i>	Chlorpyrifos	Diuron (200 µg/L)	1.5	Lydy & Austin 2004
<i>Hyalella azteca</i>	Chlorpyrifos	Atrazine (10 µg/L)	1.0	Anderson & Lydy 2002
<i>Hyalella azteca</i>	Chlorpyrifos	Atrazine (40 µg/L)	1.6	Anderson & Lydy 2002
<i>Hyalella azteca</i>	Chlorpyrifos	Atrazine (80 µg/L)	2.0	Anderson & Lydy 2002
<i>Hyalella azteca</i>	Chlorpyrifos	Atrazine (200 µg/L)	2.8	Anderson & Lydy 2002
<i>Chironomus tentans</i>	Chlorpyrifos	Atrazine (10 µg/L)	1.0	Belden & Lydy 2000
<i>Chironomus tentans</i>	Chlorpyrifos	Atrazine (40 µg/L)	1.83	Belden & Lydy 2000
<i>Chironomus tentans</i>	Chlorpyrifos	Atrazine (80 µg/L)	2.75	Belden & Lydy 2000
<i>Chironomus tentans</i>	Chlorpyrifos	Atrazine (200 µg/L))	4.00	Belden & Lydy 2000

¹ SR = synergistic ratio, which is equivalent to K = interaction coefficient; each is the ratio of the EC₅₀ of the pesticide alone to the EC₅₀ of the pesticide in the presence of a non-toxic concentration of the synergist.

Table 4.11 Predicted LC₅₀ values for threatened or endangered species; ICE v. 1.0.

Species	Common Name	Family	LC ₅₀ (µg/L)	Surrogate
<i>Oncorhynchus tshawytscha</i>	Chinook Salmon	Salmonidae	9.2	<i>Oncorhynchus mykiss</i>
<i>Oncorhynchus kisutch</i>	Coho Salmon	Salmonidae	7.3	<i>Oncorhynchus mykiss</i>
<i>Oncorhynchus clarki henshawi</i>	Lahontan cutthroat trout	Salmonidae	4.0	<i>Oncorhynchus mykiss</i>
<i>Gila elegans</i>	Bonytail chub	Cyprinidae	186	<i>Pimephales promelas</i>
<i>Ptychocheilus lucius</i>	Colorado squawfish	Cyprinidae	171	<i>Pimephales promelas</i>

Table 4.12. Level I fugacity model inputs.

Inputs	Value
Molecular weight	350.6
Temperature (°C)	25
log K _{OW}	4.96
Water Solubility (mg/L)	1.46
Vapor Pressure (Pa)	2.36 x 10 ⁻³
Melting Point (°C)	42.73
Henry's Constant (Pa·m ³ /mol) ¹	0.567
Partition coefficients ¹	
Organic carbon-water (L/kg)	37,392
Air-water (dimensionless)	2.29 x 10 ⁻⁴
Suspended particles-water (dimensionless)	3,590
Fish-water	4,560
Compartment volumes (m ³)	
Air	10 ¹⁴
Aerosol	2000
Water	2 x 10 ¹¹
Suspended particles	10 ⁶
Fish	2 x 10 ⁵
Sediment	10 ⁸
Chlorpyrifos concentration in water (ng/L)	10.5
Fish lipid levels (%)	0.5-20%
Suspended sediment organic carbon content (%)	0.5-20%
Sediment (%)	0.5-20%

¹ Calculated/estimated by model based on log K_{OW}.

Table 4.13 Level I fugacity model outputs; chlorpyrifos concentrations in non-water environmental compartments with varying levels of fish lipids, suspended sediment organic carbon and sediment organic carbon; water concentration is 10.5 ng/L in all cases.

Lipid (%)	Chlorpyrifos concentrations							Mass (kg)
	Suspended Sediment Organic Carbon (%)	Sediment Organic Carbon (%)	Fish (ng/g)	Suspended sediment (ng/g)	Sediment (ng/g)	Air (ng/m ³)	Aerosol (ng/m ³ air)	
0.5	0.5	0.5	4.8	2.0	2.0	2.4	0.08	2820
1	0.5	0.5	4.8	2.0	2.0	2.4	0.08	2820
5	0.5	0.5	48	2.0	2.0	2.4	0.08	2820
10	0.5	0.5	96	2.0	2.0	2.4	0.08	2850
15	0.5	0.5	144	2.0	2.0	2.4	0.08	2850
20	0.5	0.5	191	2.0	2.0	2.4	0.08	2850
0.5	1	0.5	4.8	3.9	2.0	2.4	0.08	2830
0.5	5	0.5	4.8	20	2.0	2.4	0.08	2860
0.5	10	0.5	4.8	39	2.0	2.4	0.08	2880
0.5	15	0.5	4.8	59	2.0	2.4	0.08	2900
0.5	20	0.5	4.8	79	2.0	2.4	0.08	2950
0.5	0.5	1	4.8	2.0	3.9	2.4	0.08	3300
0.5	0.5	5	4.8	2.0	20	2.4	0.08	7050
0.5	0.5	10	4.8	2.0	39	2.4	0.08	11800
0.5	0.5	15	4.8	2.0	59	2.4	0.08	16500
0.5	0.5	20	4.8	2.0	78	2.4	0.08	21100

List of Appendices:

4A - Comparison of values used in EPA, CDFG and UCD chlorpyrifos criteria reports

4B - Data summary sheets for data rated relevant and reliable

4C - Data and calculations for distribution fit test

Appendix 4A
Comparison of values used in EPA, CDFG and UCD chlorpyrifos criteria
reports

Comparison of the acute toxicity values used by USEPA, California Department of Fish and Game (CDFG) and the UC Davis (UCD) for deviation of water quality criteria for chlorpyrifos.

Objective and overview

Data used by different agencies in calculating acute water quality criteria for chlorpyrifos were tabulated for side by side comparison (Table A-1). Studies excluded by UCD, but included in either the CDFG or EPA criteria were further examined to identify the reasons they were excluded. This information, described in Part I of the text below, was used to try to generalize the differences in the screening methods of each agency. In Part II, the reasons EPA and CDFG excluded studies were summarized as another way to compare the data quality requirements of different agencies. Part III of the text describes a comparison of criteria derived by the Burr Type III and log-triangular distributions. Both calculations were performed using the data sets from different agencies, plus a hypothetical combination data set (UCD data set plus excluded data), as examples of how the presence of different values affects the final criteria. Table A-2 compares the resulting criteria and Tables A-3 and A-4 display these values used in the distributions. A graph of the different distributions modeling the UCD data set is included in Figure A-1. Part IV is a comparison of the values used to calculate the ACR for the chronic criterion.

Brief summary of comparison

Overall, EPA and CDFG requirements for acceptable data are similar to those of UCD. For example UCD, EPA, and CDFG all exclude studies that do not report acceptable control survival. UCD selection was more stringent on the chemical grade used and not using values reported as $>$ or $<$, but these accounted for fewer unused/used data than the following factors.

Two factors that influenced data selection:

- 1) The most important factor was date of publication or data availability. The EPA report was published in 1986 and CDFG report was from 2000. Studies published after 1986 and 2000 were some of the lowest values in UCD criteria and were not in EPA and CDFG reports.
- 2) Another difference in data selection was that EPA and CDFG decided 16 values contained in a few specific sources (discussed in Part I) were acceptable using other information. In some cases it was stated that the agency assumed the studies were conducted well because of the reputation of the laboratory or because the study cited ASTM methods.

Influence of two above factors on criteria:

The choice of statistical distribution changed the resulting criteria somewhat, but did not seem to have as much influence as data selection (as seen by the use of different data sets). The Burr Type III distribution did not have a one-way effect on criteria compared to the final result from the log-triangular for the same data set. In some cases resulting criteria were lower than that calculated by log-triangular, in one case it was higher (see Table A-2). Using a different calculation method, the result from the same data set changed by a factor of 2.6 or less, while the different data sets resulted in criteria that were different by a factor of 6 or less.

Data selection was found to have more influence than the distribution on the resulting criteria. Two main factors described above seem to be responsible for most of the differences in the data sets. One or both of these factors could be influencing criteria. The second factor however, did not seem to have a great effect on the resulting criteria, because adding these values back into the UCD data set did not increase the resulting criteria much compared to the result from the EPA data set. Since exclusion of values (Factor 2 from above) was not found to be very influential, the inclusion of lower values (Factor 1 from above) probably made the biggest difference. The findings of this comparison suggest that the most important factor influencing the criteria values was the date of publication.

PART I

Reasons studies were excluded by UCD, while the values were used by CDFG and/or EPA

UCD excluded some of the acute values that were used in CDFG and EPA chlorpyrifos criteria reports. This section summarizes main reasons those studies were excluded by UCD.

First, the number of acute values used by agency was counted. The EPA report had the least number of values used, 20, UCD used 30 values, and CDFG used the most values, 33. (In this count, if multiple values were used from the same study for the same species, they are not counted separately.)

There were 23 values used by CDFG or EPA that were excluded by UCD. The reasons UCD did not use the values from those studies are listed below with the number of exclusions followed by the reason:

- (16) control survival not reported*
- (6) of the 16 above also were excluded because < 80% pure compound was used
- (3) were acceptable, but preferable values were available (more sensitive endpoint available, standard temperature available, or test with measured concentrations available)
- (1) was not obtained - from the study title and CDFG description, it appears to have tested only a mixture of chlorpyrifos and diazinon.
- (2) no toxicity values calculated

- (1) lack of other parameters that had less weight in rating system (water quality parameters not reported, concentrations used not reported, no standard method, temp not held to ± 1 °C)

*Of the 16 studies where unreported control survival was the principal for exclusion, most came from Mayer and Ellersieck, (1986) Johnson and Finley (1980), and a few came from Sanders (various studies). See Part II below about CDFG review for more explanation.

Judging by the list above, UCD selection was more stringent on the chemical grade used and not using values reported as > or <.

PART II

Overall, the reasons EPA and CDFG give for excluding studies are similar to UCD. The main difference between UCD and CDFG seems to be that they used citations to ASTM methods and lab reputation to conclude lacking references were acceptable. However, to impartially select only high quality studies UCD requires important information to be reported and preferably original study reports be used.

CDFG exclusion of studies

The CDFG diazinon and chlorpyrifos criteria document contains an appendix that summarizes and briefly discusses why studies were used or not used, including both saltwater and freshwater data. The 24 studies rejected often had more than one of the reasons below.

- (14) cited control survival not reported
- (10) have several reasons, including:
 - duration not 96 h
 - dissolved oxygen low/ not reported
 - percent active ingredient low/ not reported
 - concentrations not reported / too few
 - water quality parameters not reported
 - species not resident in North America

Note about Mayer and Ellersieck (1986), Johnson and Finley (1980)

Description from CDFG (Siepmann & Finlayson 2000) criteria report:
 "Mayer and Ellersieck (1986) - In 1986, a study was conducted by the Fish and Wildlife Service to generate static acute toxicity test data for 410 chemicals with 66 freshwater species. All tests were performed at the Columbia National Fisheries Research Laboratory and its field laboratories between 1965 and 1984. The studies on technical grade chlorpyrifos (97%) were conducted with eight species. The tests were generally in compliance with ASTM (1980) and EPA (1975) standards. At least five concentrations of chlorpyrifos were tested. Two replicates per concentration were tested. Depending on the species, water quality parameters during the tests were as follows: temperature of 2.0°C to 29°C; pH of 6.0 to 9.0; and hardness of 44 mg/L to 272 mg/L. Control survival,

dissolved oxygen, and measurement of chlorpyrifos concentrations were not discussed.... Although information about some important test characteristics could not be obtained, most of these data were accepted because of the use of ASTM guidelines and the reputation of the laboratory...."

Most of the data in Johnson and Finley (1980) is also reported in Mayer & Ellersieck (1986). Mayer & Ellersieck (1986) states to assume all tests met cited ASTM and EPA methods. Johnson and Finley 1980 describe methods in detail, but not use of controls. Values from Sanders and Cope (1968), Sanders (1969), and Macek *et al.* (1969) are also repeated in Mayer & Ellersieck (1986) and Johnson and Finley (1980).

From the UCD methods perspective, to be fair and impartial in rating quality of all studies, one should refrain from making such assumptions and evaluate only information reported.

EPA exclusion of studies

EPA documents contain an unused data section in which a reason for exclusion of a study is followed by citations of studies omitted for that reason. Freshwater and saltwater data are mixed in this section that contains 60 excluded studies.

Number of times a parameter was used to exclude a value, followed by the reason:

- (1) the species was not resident in North America
- (4) organisms were probably previously exposed to other pesticides or pollutants
- (12) tests were on commercial formulation
- (13) the source of chlorpyrifos was not adequately described
- (2) organisms were exposed by injection, gavage, or in food
- (10) organisms were fed in short term tests
- (2) the concentration of solvent was too high
- (7) polyethylene test chambers were used and concentration of chlorpyrifos not measured
- (4) tests were conducted in distilled or deionized water without adding appropriate salts
- (1) control mortality was high
- (2) test procedures were inadequately describe
- (7) they contain data that have been published elsewhere

Additionally, examination of data tables and species mean acute values show that acceptable values from static tests with fish were not used if acceptable values were available from flow through tests.

PART III

Comparison of Burr Type III and log-triangular criteria calculation with all three data sets

Methods

To examine how the different values selected may influence the final criteria calculation, the log-triangular method and Burr Type III method were used to calculate criteria for each agency's data set. To address the criticism that criteria derived by the UCD method were lower simply because it excluded higher values contained mostly in Mayer & Ellersieck (1986), a hypothetical combination data set was created by adding excluded values back into the UCD data set. This was done by starting with the UCD data set (as it is in Table A-3) and adding in any species values from EPA data where UCD had none, (or from CFDG if EPA had none). This was a way to test if the UCD criteria was lower because of the values selected, particularly the exclusion of several higher values.

For the log-triangular calculation, Genus Mean Acute Values (GMAVs) were used following EPA (1985) methods. For the Burr Type III calculation Species Mean Acute Values (SMAVs) were used. SMAVs were calculated as the geometric mean of all LC₅₀ values for the same species. Then, GMAVs were calculated as the geometric mean of all species values in the same genus. For the Burr Type III calculation the chosen percentile and confidence level used was the same as in UCD criteria reports: the 5th percentile at 50% confidence. These results are presented in Tables A-3 and A-4. For the log-triangular calculation, the lowest 4 values are repeated at the bottom of the table for easy comparison as those values are weighted heavily in this calculation.

Plots of the distributions used, plus other commonly used distributions were included as Figure A-1. The EPA log-triangular is graphed following the procedure in USEPA 1985 and the Burr Type III distribution was constructed using the fit parameters obtained from the BurrliOZ software (CSIRO 2001). Parameters used to plot the log-logistic function were derived using the ETX 1.3 (Aldenberg 1993). The log-normal distribution was constructed using Excel and all of these functions were plotted in the same graph using Excel (v. 9.0.7). Also, the SMAVs of each agency (values used for the Burr III distribution, in Table A-4) are also plotted in Figure A-2 for visual comparison.

Results

Using these different data sets and methods, the resulting criteria ranged from 0.084 to 0.01 µg/L and appeared to depend somewhat more on the data set than the method of calculation. Using a different calculation method, the result from the same data set changed by a factor of 2.6 or less, while the different data sets resulted in criteria that were different by a factor of 6 or less. The Burr Type III distribution did not have a one-way effect on criteria compared to the final result from the log-triangular for the same data set (Table A-2). With the EPA, UCD, and hypothetical data sets, the resulting criteria were lower than that calculated by log-triangular, but for the CFDG data set the criterion from the Burr III method was higher.

Comparing the data sets for all the calculations, the lowest criterion is from the UCD data set. The reason these are lower is probably largely due to inclusion of more recent publications that yielded more sensitive LC₅₀ values. The lowest values included in the UCD document were those for *Hyaella azteca* (Anderson & Lydy 2002), *Simulium vittatum* IS-7 (Hyder *et al.* 2004), *Proclleon sp.* (Anderson *et al.* 2006), and

Ceriodaphnia dubia (various refs 1992-2004, see Table A-1), which are all published after the EPA 1986 and the CDFG 2000 report.

Also, there was exclusion of several of the higher values from the UCD report because they rated low. Many of these values came from Mayer & Ellersieck (1986) and the methods were not documented well, as discussed in Part I. Addition of these excluded values to the UCD set, as done in the Combination data set, brings the calculated criteria up (to 30 and 20 µg/L: from Log-T & Burr III), closer to EPA's values (84 and 60 ng/L), but it is still closer to the UCD values (26 and 10 ng/L), using both calculation methods. Since adding the excluded high values back into the data set did not increase the criteria much (the criterion is still closer to the result from the UCD data set vs. the result from the EPA data set), this suggests that it is mostly the inclusion of the more recently published lower values driving the UCD value to be lower than those of the other agencies. (The Combination data set includes all excluded values, if ONLY data in Mayer and Ellersieck (1986) are added back to the UCD data set and species mean values recalculated, then the UCD acute criterion using the Burr III distribution increases from 10 to 20 ng/L.)

In the log-triangular calculation (Table A-3), the lowest 4 values of the combination data set are the same as the UCD data set, while the criterion is higher from the combination data set (26 vs. 30 ng/L). This shows that increasing the number of values in the data set raised the criterion. When using Burr Type III distribution (Table A-4) the combination data set is also higher (20 vs. 10 ng/L), but it is not clear that it is from just the greater number of data or the influence of the new values.

Figure A-1 shows how the EPA log-triangular fits the data at the sensitive end very closely, while the other distributions fit the overall trend of entire data set better. Fitting the sensitive end well can be an advantage; however, the limitation is that the distribution is more dependent on the lowest 4 values accurately representing the sensitive species in the ecosystem. On the other hand, a distribution that considered all the data will be not be as easily influenced by a change in one of the values at the low end.

In summary, the Burr Type III distribution with UCD values produced the lowest criteria. Overall, the results of the calculation methods appeared to not have as much influence as data selection. The differences in the resulting chlorpyrifos criteria come from: 1) inclusion of lower data by certain agencies because of a more recent date of publication; 2) the exclusion of values because thorough documentation of the methods were not available, as discussed in Part I; and 3) to a lesser degree, the methods (log-triangular/ Burr Type III) used to calculate the criterion.

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Table A-1. Comparison of Acceptable Acute Values for Chlorpyrifos Criteria by Agency

Y- indicates agency used that value. Where disputed, the value used is shown. Only studies that at least one agency stated were acceptable are included.

Species, Common Identifier	LC/EC ₅₀ (µg/L)	EPA 1986	CDFG 2000	UCD 2007	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
<i>Aplexa hypnorum</i> , Snail	>806	Y	Y		Phipps and Holcomb 1985	LR: 6	
<i>Carassius auratus</i> , Goldfish	>806	Y	Y		Phipps and Holcomb 1985	LR: 6	
<i>Ceriodaphnia dubia</i> , Cladoceran	0.053		Y	Y	Bailey <i>et al.</i> (1997)		
	0.055		Y	Y			
	0.13		Y	Y	CDFG 1992 Test No. 150		
	0.08		Y	Y	CDFG 1992 Test No. 139		
	0.038		Y		CDFG 1999 (Test No. 68)		UCD did not obtain- CDFG describes a mixture test with diazinon
	0.0396			Y	CDFG 1999 Test No. 61 (used 96h data)		
	0.39			Y	Belden & Lydy (2000)		
<i>Chironomus tentans</i> , Insect	0.16			Y	Belden & Lydy (2006)		
	0.17			Y	Lydy & Austin (2005)		
	0.58		Y		Pape-Lindstrom & Lydy 1997	Acceptable: b	
	0.75		Y			Acceptable: b	
	0.51		Y			Acceptable: b	
<i>Claassenia sabulosa</i> , Insect	0.57	Y	Y		Sanders and Cope (1968); Johnson and Finley (1980)/ Mayer & Ellersieck (1986)	LL: 4,7	
<i>Daphnia ambigua</i> , Cladoceran	0.035			Y	Harmon <i>et al.</i> (2003)		
	0.1			Y	Burgess 1988		
<i>Daphnia magna</i> , Cladoceran	1		Y	Y	Kersting & Van Wijngaarden (1992)		

Table A-1. Comparison of Acceptable Acute Values for Chlorpyrifos Criteria by Agency

Y- indicates agency used that value. Where disputed, the value used is shown. Only studies that at least one agency stated were acceptable are included.

Species, Common Identifier	LC/EC ₅₀ (µg/L)	EPA 1986	CDFG 2000	UCD 2007	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
<i>Daphnia pulex</i> , Cladoceran	0.25			Y	Van Der Hoeven & Gerritsen (1997)		This value was for mobility
	0.3		Y			Acceptable: d	This value was for mortality
<i>Gammarus fasciatus</i> , Amphipod	0.32	Y			Sanders 1972	LL: 4,7	CDFG: control described, survival NR
<i>Gammarus lacustris</i> , Amphipod	0.11	Y	Y		Sanders 1969; Johnson and Finley 1980	LN: 1,4	CDFG: control survival 100%
<i>Gammarus pseudolimnaeus</i> , Amphipod	0.18	Y			Siefert <i>et al.</i> 1984	N:1,4	
<i>Hyalella azteca</i> , Amphipod	0.0427			Y	Anderson & Lydy (2002)		
	0.138		138	Y	Brown 1997		CDFG confused units, should be 0.138
<i>Ictalurus punctatus</i> , Catfish	280		Y		Johnson and Finley 1980/ Mayer & Ellersieck 1986	LL: 4,7	EPA: acceptable:g
	806	Y	Y	Y	Phipps & Holcombe (1985)		
<i>Lepomis macrochirus</i> , Bluegill	2.4		Y		Johnson and Finley 1980/ Mayer & Ellersieck (1986)	LL: 4,7	EPA: acceptable:g
	4.2		Y		Mayer & Ellersieck (1986)	LL: 4,7	
	1.8		Y				
	2.5		Y				
	1.7		Y				
	5.8			Y	Bowman 1988		
	10	Y	Y	Y	Phipps & Holcombe (1985)		
<i>Neomysis mercedis</i> , Opossum shrimp	0.15		Y	Y	CDFG 1992, Test 143		
	0.16		Y	Y	CDFG 1992, Test 133		
	0.14		Y	Y	CDFG 1992, Test 142		

Table A-1. Comparison of Acceptable Acute Values for Chlorpyrifos Criteria by Agency

Y- indicates agency used that value. Where disputed, the value used is shown. Only studies that at least one agency stated were acceptable are included.

Species, Common Identifier	LC/EC ₅₀ (µg/L)	EPA 1986	CDFG 2000	UCD 2007	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
<i>Neoplea striola</i> , Pygmy back-swimmer	1.22	Y			Siefert et al. 1984	N:1,4	
	1.56	Y					
<i>Oncorhynchus (Salmo) clarki</i> , Cutthroat trout	18.4	Y	Y		Johnson and Finley 1980/ Mayer & Ellersieck (1986)	LL: 4,7	
	5.4		Y		Mayer & Ellersieck (1986)	LL: 4,7	
	26		Y				
	13.4		Y				
<i>Oncorhynchus mykiss (Salmo gairdneri)</i> , Rainbow trout	8	Y	Y	Y	Holcombe <i>et al.</i> (1982)		
	7.1		Y		Macek <i>et al.</i> 1969; Johnson and Finley 1980/Mayer & Ellersieck (1986)	LL: 4,7	EPA: Acceptable:g
	9	Y			Phipps & Holcombe (1985)	Acceptable: e	CDFG: listed as acceptable, but seems to have not been included (SMAV in report is 7.5 = geomean of 8 and 7.1)
	25			Y	Bowman 1988		
<i>Oncorhynchus tshawytscha</i> , Chinook salmon	15.96			Y	Wheelock <i>et al.</i> (2005)		
<i>Orconectes immunis</i> , Crayfish	6	Y	Y	Y	Phipps & Holcombe (1985)		
<i>Peltodytes sp.</i> , Water beetle	0.8	Y	Y		Federle and Collins 1976	RN: 7 SM, conc NR, DO, H, A, C, pH, P, Hyp, Org. source, temp not ± 1 °C, > 0.05% solvent in control, no reps, fed NR	
<i>Pimephales promelas</i> ,	200		Y	Y	Geiger <i>et al.</i>		

Table A-1. Comparison of Acceptable Acute Values for Chlorpyrifos Criteria by Agency

Y- indicates agency used that value. Where disputed, the value used is shown. Only studies that at least one agency stated were acceptable are included.

Species, Common Identifier	LC/EC ₅₀ (µg/L)	EPA 1986	CDFG 2000	UCD 2007	Reference	UCD Rating: Reason for Exclusion (see end of table for key)	Comments
Fathead minnow					(1988)		
	506		Y			Acceptable: e	
	203	Y	Y	Y	Holcombe <i>et al.</i> (1982)		
	140		Y	Y	Jarvinen & Tanner (1982)		
	542	Y	Y		Phipps & Holcombe (1985)	Acceptable: e	
<i>Proclonus sp.</i> , Insect	0.1791			Y	Anderson <i>et al.</i> (2006)		
	0.0704			Y			
	0.0798			Y			
<i>Pteronarcella badla</i> , Insect	0.38	Y	Y		Sanders and Cope 1968	NN: 1,4	
<i>Pteronarcys californica</i> , Insect	10	Y	Y		Sanders and Cope 1968; Johnson and Finley 1980	Sanders and Cope 1968: NN: 1,4	
<i>Pungitius pungitius</i> , Stickleback	4.7			Y	Van Wijngaarden <i>et al.</i> (1993)		
<i>Salvelinus namaycush</i> , Lake trout	98	Y			Johnson and Finley 1980	LL: 4,7	
	244		Y		Mayer & Ellersieck (1986)	LL: 4,7	CDFG: used Mayer & Ellersieck (1986) -value 98 was static test, 244 was FT
<i>Simulium vittatum</i> IS-7, Insect	0.06			Y	Hyder <i>et al.</i> (2004)		
<i>Trichopteran leptoceridae sp.</i> , Insect	0.77	Y			Siefert <i>et al.</i> 1984	N:1,4	
<i>Xenopus laevis</i> , Frog	2,410			Y	El-Merhibi <i>et al.</i> (2004)		
Total individual values	66	21	42	33			
Studies used (values for different species in the same study counted separately)	53	20	33	30			

Codes for reasons for exclusion in the Table A-1.

This table includes all values used by any of the three agencies. Reports from all agencies mention many studies that were judged unacceptable that were not included reports by other agencies. Because of the large number of these studies, they were not included in this table.

Y- indicates values were USED by agency

Acceptable: - indicated values were ACCEPTABLE, BUT NOT USED by specified agency because more preferable data were available. Details are in the following list.

- a. 96-h result available
- b. Test with measured concentrations available
- c. 48-h result available
- d. More sensitive endpoint available
- e. Non-standard temperature
- f. More sensitive lifestage available
- g. Flow-through test available

UCD ratings (see Chapter 3 for details), major reasons for L or N ratings are summarized with the codes below

R = Relevant or reliable

L = Less relevant or less reliable

N = Not relevant or not reliable

Major reasons for studies rated UNACCEPTABLE by UCD only.

These studies were rated LR, RL, LL, RN, LN, N according to UCD methods (see Chapter 3 for details)

- 1. Chemical grade was lower than 80% pure
- 2. Endpoint not linked to population effects
- 3. Family not in North America
- 4. Control response was not acceptable or not reported
- 5. Not a freshwater test
- 6. No toxicity value calculated
- 7. Low reliability score- based on reporting of many parameters including those listed just below

For studies excluded only because of low reliability score (#7 from table above) more information was given with the following abbreviations

NR- not reported

SM- no standard method

Conc NR- concentrations not reported

Conc NM- concentrations not measured (nominal)

Org- organism

Control desc. -control not described

DO - dissolved oxygen NR

H-hardness NR

A- alkalinity NR

C-conductivity NR

pH- pH NR

T- temperature NR

P-photoperiod NR

Hyp-hypotheses tests statistics

% solvent -if solvent in control or the percent not reported or too high, as indicated

Table A-2. Criteria comparison by data set and calculation methods.

Criteria (in µg/L) are shown with number of values in the data set in parentheses.

Method of calculation	Data Set			
	EPA 1986	CDFG 2000	UCD 2007	Hypothetical Combination (UCD data set plus excluded data)
Log-Triangular	0.084 (15)	0.026 (18)	0.026 (14)	0.030 (24)
Burr Type III	0.060 (18)	0.04 (20)	0.01 (17)	0.02 (30)
Criterion from agency report	0.08345 (15)	0.02 (18)	0.01 (17)	NA

Table A-3. Log-Triangular Calculation (EPA Method) for Chlorpyrifos Genus Mean Acute Values

Genus species	Chlorpyrifos Genus Mean Acute Values (µg/L)			
	EPA 1986	CDFG 2000	UCD 2007	Hypothetical Combination
Xenopus laevis			2410	2410
Aplexa hypnorum	>806	>806		806
Carassius auratus	>806	>806		806
Ictalurus punctatus	806	475	806	806
Pimephales promelas	332	274	178	178
Salvelinus namaycush	98	244		98
Hyaella azteca		138	0.077	0.077
Oncorhynchus clarki, mykiss, tshawytscha	12.36	10.1	15	15
Pteronarcys californica	10	10		10
Lepomis macrochirus	10	3.03	7.6	7.6
Orconectes immunis	6	6	6	6
Pungitius pungitius			4.7	4.7
Neoplea striola	1.38			1.38
Peltodytes sp.	0.8	0.8		0.8
Leptoceridea sp.	0.77			0.77
Chironomus tentans		0.6	0.22	0.22
Claassenia sabulosa	0.57	0.58		0.57
Pteronarcella badla	0.38	0.38		0.38
Daphnia ambigua, magna, pulex		0.54	0.14	0.14
Gammarus fasciatus, lacustris, pseudo.	0.185	0.11		0.185
Neomysis mercedis		0.15	0.15	0.15
Procladius sp.			0.1	0.1
Ceriodaphnia dubia		0.06	0.0654	0.0654
Simulium vittatum IS-7			0.06	0.06
<hr/>				
Lowest 4 values	0.77	0.38	0.1	0.1
	0.57	0.15	0.077	0.077
	0.38	0.11	0.0654	0.0654
	0.185	0.06	0.06	0.06
<hr/>				
Log-Triangular Results				
Number of values	15	18	14	24
FAV/ 5th percentile*	0.1670	0.051	0.052	0.060
Criterion	0.084	0.026	0.026	0.030
Criterion from agency report	0.08345	0.020**	0.010	

*The calculation yields a 5th percentile value (or the final acute value, FAV). This value is divided by 2 to obtain the criterion in both methods.

**Author's note: Calculated criteria do not always match the criterion reported in agency report. This has been double checked. The differences may be due to rounding.

Table A-4. BurrIII Calculation for Chlorpyrifos Species Mean Acute Values. These values are also plotted in Figure A-2.

Genus species	Chlorpyrifos Species Mean Acute Values (µg/L)			
	EPA	1986	CDFG 2000	UCD 2007 Hypothetical Combination
Xenopus laevis				2410
Aplexa hypnorum	>806		>806	806
Carassius auratus	>806		>806	806
Ictalurus punctatus	806		475	806
Pimephales promelas	332		274	178
Salvelinus namaycush	98		244	98
Hyaella azteca			138	0.077
Oncorhynchus clarki	18		13.6	18
Oncorhynchus tshawytscha				15.96
Pteronarcys californica	10		10	10
Lepomis macrochirus	10		3.03	7.6
Oncorhynchus mykiss	8.5		7.5	14.1
Orconectes immunis	6		6	6
Pungitius pungitius				4.7
Daphnia magna			1	0.32
Neoplea striola	1.38			1.38
Peltodytes sp.	0.8		0.8	0.8
Leptoceridea sp.	0.77			0.77
Chironomus tentans			0.60	0.22
Claassenia sabulosa	0.57		0.58	0.57
Pteronarcella badla	0.38		0.38	0.38
Daphnia ambigua				0.035
Daphnia pulex			0.3	0.25
Gammarus fasciatus	0.32			0.32
Neomysis mercedis			0.15	0.150
Gammarus lacustris	0.18		0.11	0.18
Gammarus pseudolimnaeus	0.11			0.11
Proclodion sp.				0.100
Ceriodaphnia dubia			0.06	0.0654
Simulium vittatum IS-7				0.06
BurrIII Results				
Number of values	18		20	17
5 th percentile	0.12		0.08	0.02
Criterion	0.060		0.04	0.01
Criterion from agency report	0.08345		0.02	0.01

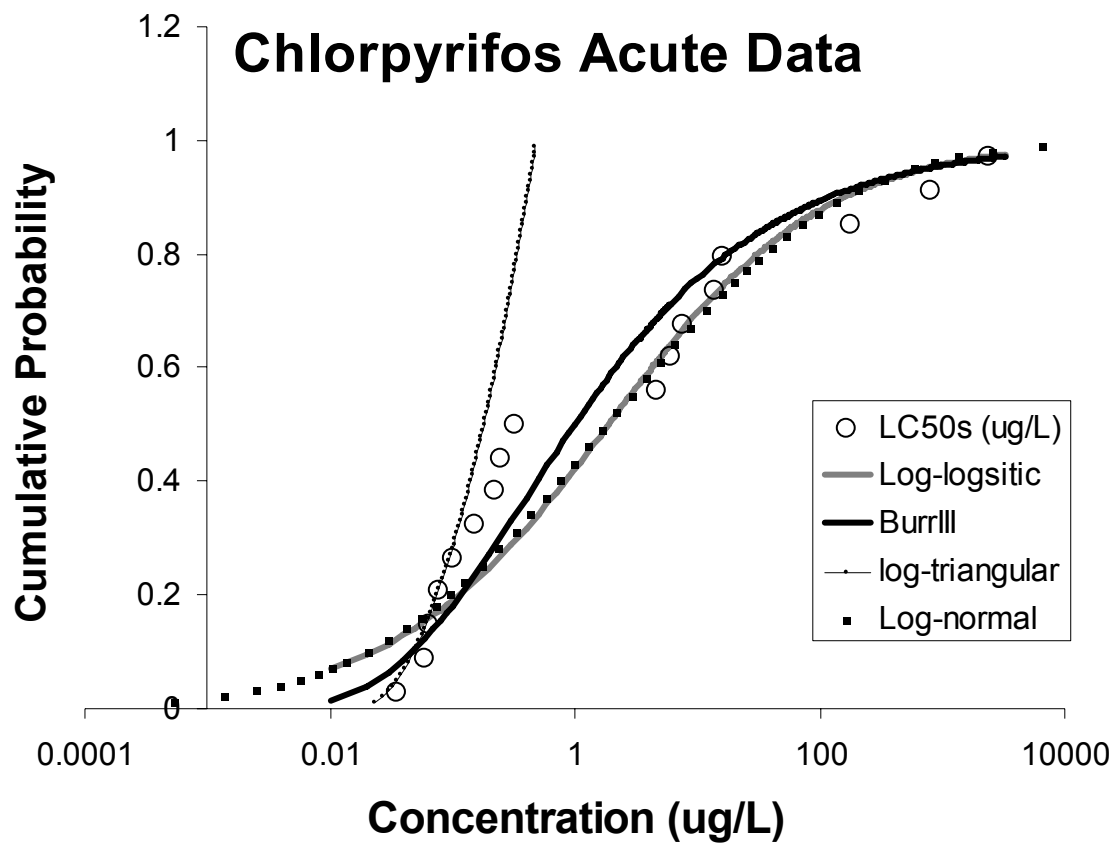


Figure A-1. The fit of several distributions to the UCD chlorpyrifos acute data set.

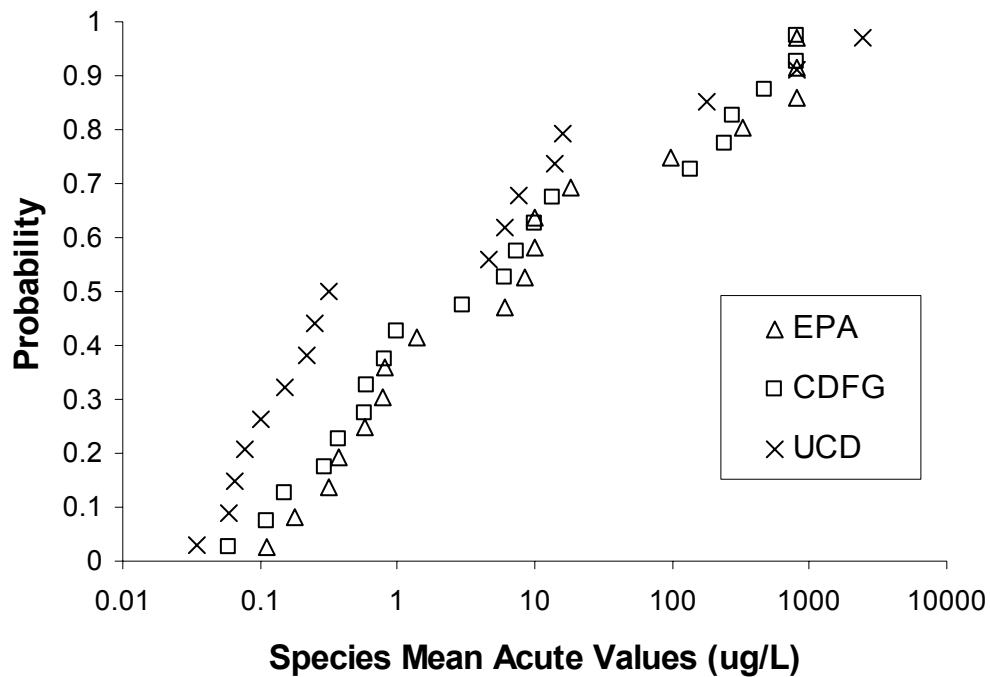


Figure A-2. The EPA, CDFG and UCD chlorpyrifos acute data sets.

Note: Equivalent LC_{50} values will not overlap because probability (on y-axis) is relative to other values in the data set. Equivalent LC_{50} values will be vertically in line with each other (according to concentration on x-axis).

Part IV

Table A-5. Comparison of studies with acute and chronic toxicity data for chlorpyrifos used in different criteria reports.

Gray shading indicates that values from that study were not considered for ACR.

Reference	Organism	EPA 1986			CDFG 2000			UCD 2007			Comment
<i>Freshwater</i>		LC ₅₀	MATC	ACR	LC ₅₀	MATC	ACR	LC ₅₀	MATC	ACR	
Jarvinen and Tanner 1982	Fathead minnow, <i>Pimephales promelas</i>				140	2.26	61.9	140	2.3	61	EPA did not use- because result of full life-cycle test available
Jarvinen and Tanner 1983	Fathead minnow, <i>Pimephales promelas</i>	170	<0.12	1,417							UCD did not use same values as EPA because NOEC not determined
Norberg and Mount 1985	Fathead minnow, <i>Pimephales promelas</i>				249	5.23	47.6				UCD did not use - purity not reported
CDFG 1999	Cladoceran, <i>Ceriodaphnia dubia</i>				0.038	0.04	0.95	0.04	0.040	1.0	Published after EPA's 1986 criteria
<i>Saltwater</i>											
McKenney <i>et al.</i> 1981	Mysid, <i>Mysidopsis bahia</i>	0.035	0.003	12.5	0.04	0.003	13.3				UCD did not use - purity not reported, control survival < 80%
Hansen <i>et al.</i> 1986	Gulf toadfish, <i>Opsanus beta</i>	520	2.276	228.5	520	2.28	228				UCD did not use - purity not reported, no standard method
Cripe <i>et al.</i> 1986	Sheepshead minnow, <i>Cyprinodon variegatus</i>	136	2.258	60.23	194	2.26	85.8				UCD did not use acute value- control not described or response reported
Goodman 1985	California grunion, <i>Leuresthes tenuis</i>	1.068	0.205	5.212				1.0	0.2	5.0	CDFG did not use - concentrations nominal, used 2.5 d old fry instead of 48 h embryos, test guidelines not mentioned.
Goodman 1985	Inland silverside, <i>Menidia beryllina</i>	4.2	1.162	3.614	4.2	1.16	3.6				UCD did not use- purity not reported, no standard method
Goodman 1985	Atlantic silverside, <i>Menidia menidia</i>	1.229	0.367	3.352							CDFG did not use -control survival 41%, test guidelines not reported. UCD did not use - purity not reported, no standard method, low control survival
Goodman 1985	Tidewater silverside, <i>Menidia peninsulae</i>	0.748	0.544	1.374	0.71	0.54	1.3				UCD did not use - purity not reported, no standard method, control survival < 80%
ACR method: All three agencies used the geometric mean of ACRs of species whose acute values were close to the FAV.											
Final ACR (species values included in bold)				4.064			3.5			2.2	

Appendix 4B
Data summary sheets for data rated relevant and reliable

Abbreviations used in this appendix:

NA = Not Applicable; for example, in a study where concentrations were not measured, NA is entered for items related to chemical method; a score of 0 is assigned for NA entries;

NC = Non Calculable; for example, if a NOEC was determined, but no LOEC, then the MATC is not calculable;

NR = Not Reported

RR = Relevant, Reliable study

Unused lines deleted from tables

Toxicity Data Summary

Ceriodaphnia dubia

Study: Bailey HC, Miller JL, Miller MJ, Wiborg LC, Deanovic L, Shed T. 1997. Joint acute toxicity of diazinon and chlorpyrifos to *Ceriodaphnia dubia*. Environ Toxicol Chem 16: 2304-2308.

Relevance

Score: 100

Rating: R

Reliability

Score: 88.5

Rating: R

Notes: Summary of data for chlorpyrifos only exposures.

Bailey et al. 1997		
Parameter	Value	Comment
Test method cited	USEPA 1991	EPA 600/4-90/027
Phylum/subphylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Ceriodaphnia</i>	
Species	<i>dubia</i>	
Family resides in	North America	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	24, 48, 72, 96 h	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	< 10%	
Temperature	25 ± 1 °C	
Test type	Static	
Photoperiod	16L:8D	
Dilution water	Moderately hard synthetic water	
pH	7.40-8.23	Water quality
Hardness	80-100 mg/L as CaCO ₃	within guidelines

Bailey et al. 1997		
Parameter	Value	Comment
Alkalinity	100-120 mg/L as CaCO ₃	in USEPA 1991
Conductivity	290-300 umhos/cm	
Dissolved Oxygen	NR	
Feeding	None	
Purity of test substance	99%	
Concentrations measured?	Yes; 81.4% of nominal	
Measured is what % of nominal?	81.4%	
Chemical method documented?	Yes	
Concentration of carrier in test solutions	< 0.1%	
Concentration 1 Nom (µg/L)	0.008	Reps: 4 w/5 per
Concentration 2 Nom (µg/L)	0.016	Reps: 4 w/5 per
Concentration 3 Nom (µg/L)	0.033	Reps: 4 w/5 per
Concentration 4 Nom (µg/L)	0.066	Reps: 4 w/5 per
Concentration 5 Nom (µg/L)	0.132	Reps: 4 w/5 per
Control	Methanol at < 0.1%	Reps: 4 w/5 per
LC50 µg/L (95% C.I.) Trimmed Spearman-Kärber or binomial; based on measured values	Test 1 24-h: 0.101 (0.079-0.130); Test 1 48-h: 0.079 (0.073-0.086); Test 1 72-h: 0.078 (0.043-0.143); Test 1 96-h: 0.053 (0.040-0.071); Test 2 24-h: 0.063 (0.056-0.072); Test 2 48-h: 0.058 (0.027-0.124); Test 2 72-h: 0.058 (0.027-0.124); Test 2 96-h: 0.055 (0.049-0.061); Test 3 24-h: 0.095 (0.083-0.109); Test 3 48-h: 0.066 (0.055-0.078); Test 4 24-h: 0.086 (0.074-0.101); Test 4 48-h: 0.064 (0.055-0.073) (Trimmed Spearman-Kärber or binomial; based on measured values)	

Reliability points taken off for:

Documentation: Dissolved oxygen (4), Hypothesis tests (8)

Acceptability: Dissolved oxygen (6), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Ceriodaphnia dubia

Study: CDFG. 1999. Test 61: 7-day chronic *Ceriodaphnia dubia* test for chlorpyrifos.
Aquatic Toxicology Laboratory, Elk Grove, California.

Relevance

Score: 100

Rating: R

Reliability

Score: Acute: 94.5, Chronic: 92.5

Rating: R

CDFG 1999		
Parameter	Value	Comment
Test method cited	USEPA 1993 and ASTM 1988 (E729-88, E1192-88)	
Phylum/subphylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Ceriodaphnia</i>	
Species	<i>dubia</i>	
Found in	N. Amer.	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	7 d	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	Dilution water: 0% Solvent: 20%	20% control mortality is limit
Effect 2	Reproduction	
Control response 2	Dilution water: 27.4 Solvent: 15.9 neonates/female	NOEC determined by comparison to solvent control
Temperature; mean (range); °C	Control: 24.6 (24.0-25.1) Test: 24.6 (24.0-25.1)	Measured in highest test concentration
Test type	Static; daily renewal	
Photoperiod	16L:8D	
Dilution water	CDFG Aquatic Tox Lab well water	Measured in highest test concentration

CDFG 1999		
Parameter	Value	Comment
pH; mean (range)	Control: 8.18 (7.97-8.47) Test: 8.32 (7.91-8.58)	Measured in highest test concentration
Hardness; mean (range); mg/L as CaCO ₃	Control: 175 (168-178) Test: 171 (168-176)	Measured in highest test concentration
Alkalinity; mean (range); mg/L as CaCO ₃	Control: 188 (184-192) Test: 186 (184-190)	Measured in highest test concentration
Conductivity; mean (range); uS/cm	Control: 381 (337-419) Test: 379 (316-407)	Measured in highest test concentration
Dissolved Oxygen; mean (range); mg/L	Control: 7.59 (5.75-9.1) Test: 7.50 (3.85-9.78)	Measured in highest test concentration
Feeding	1:1 YCT: <i>Selenastrum</i> after loading and after daily renewal	
Purity of test substance	99.8% (Dursban R)	
Concentrations measured?	Yes	
Measured is what % of nominal?	82-300%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	≤ 0.125 mL/L	
Concentration 1 Nom/Meas (µg/L)	0.004/0.012	Reps: 10 w/1 per
Concentration 2 Nom/Meas (µg/L)	0.008/0.022	Reps: 10 w/1 per
Concentration 3 Nom/Meas (µg/L)	0.016/0.015	Reps: 10 w/1 per
Concentration 4 Nom/Meas (µg/L)	0.033/0.029	Reps: 10 w/1 per
Concentration 5 Nom/Meas (µg/L)	0.066/0.054	Reps: 10 w/1 per
Control	Dilution water; solvent (methanol ≤ 0.125 mL/L)	Reps: 10 w/1 per
LC50 (95% C.I.); ug/L	7-d: 0.039 (0.038-0.040); Data are available to calculate LC50 24, 48, 72, etc up to 7 d	Trimmed Spearman-Kärber
ECx; indicate calculation method	NC, but it may be possible to calculate from raw data	
NOEC; ug/L	Survival: 0.029 Reproduction: 0.029 (MSD = 4.9)	Survival: Fisher's exact, Reproduction: Dunnett's
LOEC; indicate calculation method	Survival: 0.054 Reproduction: 0.054	
MATC (GeoMean NOEC,LOEC)	Survival: 0.0396 Reproduction: 0.0396	
% of control at NOEC	Survival: 100% Reproduction: 134%	Compared to solvent control
% of control at LOEC	Survival: 10% Reproduction: 13.2%	Compared to solvent control

Application factors or ACRs: Determine 96-h LC50, then calculated ACR for this test:

96-h LC50 by Trimmed Spearman Karber = 0.0396 ug/L.

MATC = 0.0396

ACR = 0.0396/0.0396 = 1.0

Reliability points taken off for:

Documentation: Statistical significance level (2), MSD (2)

Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.1 mL/L (4: chronic only, OK in acute), Adequate replication (2), Minimum significant difference (MSD) upper bound acceptable (1)

Toxicity Data Summary

Ceriodaphnia dubia

Study: CDFG. 1992c. Test No. 139. 96-h acute toxicity of chlorpyrifos to *Ceriodaphnia dubia*.

Relevance

Score: 100

Rating: R

Reliability

Score: 91.5

Rating: R

CDFG 1992c		
Parameter	Value	Comment
Test method cited	ASTM 1988; USEPA 1993	
Phylum/subphylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Ceriodaphnia</i>	
Species	<i>dubia</i>	
Found in	N. Amer.	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	10%	
Temperature; mean (range); °C	24.3 (23.7-24.8)	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water	
pH; mean (range)	8.2 (8.0-8.6)	
Hardness; mean (range); mg/L as CaCO ₃	122 (120-123)	
Alkalinity; mean (range); mg/L as CaCO ₃	105 (104-106)	

Conductivity; mean (range); uS/cm	334 (320-350)	
Dissolved Oxygen; mean (range); mg/L	7.7 (6.9-8.1)	
Feeding	YCT: <i>Selenastrum</i> 2 h prior to test and 2 hr prior to each renewal	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	92.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	≤ 0.00787 mL/L	
Concentration 1 Meas ($\mu\text{g/L}$)	0.02	Reps: 4 w/5 per
Concentration 2 Meas ($\mu\text{g/L}$)	0.03	Reps: 4 w/5 per
Concentration 3 Meas ($\mu\text{g/L}$)	0.07	Reps: 4 w/5 per
Concentration 4 Meas ($\mu\text{g/L}$)	0.135	Reps: 4 w/5 per
Concentration 5 Meas ($\mu\text{g/L}$)	0.285	Reps: 4 w/5 per
Control	Dilution water; solvent (triethylene glycol dimethyl ether, triethylene glycol, ≤ 0.00787 mL/L)	Reps: 4 w/5 per
LC50 (95% C.I.); ug/L	0.08 (0.06-0.11)	Moving average
NOEC; ug/L	0.07	Chi square (no MSD reported)
LOEC; ug/L	0.135	
MATC (GeoMean NOEC,LOEC)	0.097	
% of control at NOEC	100%	
% of control at LOEC	11%	

Reliability points taken off for:

Documentation: Nominal concentrations (3), Statistical significance level (2), MSD (2)

Acceptability: Measured concentrations within 20% Nom (4), Temperature not held to $\pm 1^\circ\text{C}$ (3), Random or block design (2), Minimum significant difference (MSD) upper bound acceptable (1)

Toxicity Data Summary

Ceriodaphnia dubia

Study: CDFG. 1992. Test No. 150. 96-h acute toxicity of chlorpyrifos to *Ceriodaphnia dubia*.

Relevance

Score: 90 (No standard method)

Rating: R

Reliability

Score: 90.5

Rating: R

CDFG 1992f		
Parameter	Value	Comment
Test method cited	ASTM 1988; USEPA 1993	Chronic method, not appropriate for acute test
Phylum/subphylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Ceriodaphnia</i>	
Species	<i>dubia</i>	
Found in	N. Amer.	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	0%	
Temperature; mean (range); °C	24.6 (24.3-25.1)	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water	
pH; mean (range)	8.3 (8.0-8.5)	
Hardness; mean (range); mg/L as CaCO ₃	120	
Alkalinity; mean (range); mg/L as CaCO ₃	107 (106-108)	

CDFG 1992f		
Parameter	Value	Comment
Conductivity; mean (range); uS/cm	326 (290-350)	
Dissolved Oxygen; mean (range); mg/L	7.7 (7.3-8.0)	
Feeding	YCT: <i>Selenastrum</i> 2 h prior to test and 2 hr prior to each renewal	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	97%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	≤ 0.00787 mL/L	
Concentration 1 Meas ($\mu\text{g/L}$)	0.02	Reps: 4 w/5 per
Concentration 2 Meas ($\mu\text{g/L}$)	0.03	Reps: 4 w/5 per
Concentration 3 Meas ($\mu\text{g/L}$)	0.08	Reps: 4 w/5 per
Concentration 4 Meas ($\mu\text{g/L}$)	0.155	Reps: 4 w/5 per
Concentration 5 Meas ($\mu\text{g/L}$)	0.36	Reps: 4 w/5 per
Control	Dilution water; solvent (triethylene glycol dimethyl ether, triethylene glycol, ≤ 0.00787 mL/L)	Reps: 4 w/5 per
LC50 (95% C.I.); ug/L	0.13 (0.1-0.19)	binomial
NOEC; ug/L	0.08	Chi square (no MSD reported)
LOEC; ug/L	0.155	
MATC (GeoMean NOEC,LOEC)	0.11	
% of control at NOEC	100%	
% of control at LOEC	20%	

Standard method was for chronic test, not appropriate for acute test also

Reliability points taken off for:

Documentation: Nominal concentrations (3), Statistical significance level (2), MSD (2)

Acceptability: No standard method (5), Measured concentrations within 20% Nom (4), Random or block design (2), Minimum significant difference (MSD) upper bound acceptable (1)

Toxicity Data Summary

Ceriodaphnia dubia

Study: Harmon SM, Specht WL, Chandler GT. 2003. A comparison of the daphnids *Ceriodaphnia dubia* and *Daphnia ambigua* for their utilization in routine toxicity testing in the Southeastern United States. Arch Environ Contamin Toxicol 45: 79-85.

Relevance

Score: 100

Rating: R

Reliability

Score: 85

Rating: R

Harmon et al. 2003		
Parameter	Value	Comment
Test method cited	ASTM E729-88a	
Phylum/sub-phylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Ceriodaphnia</i>	
Species	<i>dubia</i>	
Found in	North America	
Age/size at start of test/growth phase	Neonates	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Immobilization	
Control response 1	Dil water = 50/50; Solvent = 50/50	
Temperature	25 ± 2 °C	
Test type	Static	glass beakers
Photoperiod	16L:8D	
Dilution water	Moderately Hard Reconstituted Water	
pH	8.11-8.66	
Hardness	54-72 mg/L as CaCO ₃	
Alkalinity	57-76 mg/L as CaCO ₃	
Conductivity	NR	

Harmon et al. 2003		
Parameter	Value	Comment
Dissolved Oxygen	7.46-9.14 mg/L	
Feeding	No	
Purity of test substance	Not stated; used research grade Dursban XP	
Concentrations measured?	Yes	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR, but ASTM method	
Concentration Meas (µg/L)	0.03	Reps: 5 w/10 per
Concentration Meas (µg/L)	0.04	Reps: 5 w/10 per
Concentration Meas (µg/L)	0.07	Reps: 5 w/10 per
Concentration Meas (µg/L)	0.09	Reps: 5 w/10 per
Concentration Meas (µg/L)	0.19	Reps: 5 w/10 per
Control?	Yes; control 1 = dilution water; control 2 = solvent control	Reps: 5 w/10 per; methanol carrier @ 37.5 uL/L
LC50; indicate calculation method	0.056 ug/L (0.054-0.059)	Trimmed Spearman-Karber (95% C.I.)

Reliability points taken off for:

Documentation: Nominal concentrations (3), Conductivity (2), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Chironomus tentans

Study: Ankley GT, Call DJ, Cox JS, Kahl MD, Hoke RA, Kosian PA. 1994. Organic carbon partitioning as a basis for predicting the toxicity of chlorpyrifos in sediments. Environ Toxicol Chem 13: 621-626.

Relevance

Score: 100

Rating: R

Reliability

Score: 75.5

Rating: R

Notes: This study includes a water-only exposure as well as sediment exposures; only water exposures are described below.

Ankley et al. 1994		
Parameter	Value	Comment
Test method cited	No standard method cited	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	<i>Chironomus</i>	
Species	<i>tentans</i>	
Family resides in	N. Amer.	
Age/size at start of test/growth phase	3 rd instar larvae	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	10 d	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	5%	
Temperature	20 ± 1° C	
Test type	Flow-through	
Photoperiod	16L:8D	
Dilution water	Dechlorinated tapwater	
pH	NR	
Hardness	NR	

Ankley et al. 1994		
Parameter	Value	Comment
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	
Feeding	daily	
Purity of test substance	99%	
Concentrations measured?	Yes, but NR	Results based on measurements corrected for recovery
Measured is what % of nominal?	NR	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Nom/Meas (µg/L)	5 nominal concentrations ranging from 15-828 ng/L	Reps: 2 w/10 per
Control	Dechlorinated tapwater	Reps: 2 w/10 per
LC50; ng/L	70 (40-130)	Trimmed Spearman-Kärber

Reliability points taken off for:

Documentation: Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Dissolved Oxygen (4), Conductivity (2), pH (3), Hypothesis tests (8)

Acceptability: Organisms randomly assigned to containers (1), Feeding (3), Hardness (2), Alkalinity (2), Dissolved Oxygen (6), Conductivity (1), pH (2), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Chironomus tentans

Study: Ankley GT, Collyard SA. 1995. Influence of piperonyl butoxide on the toxicity of organophosphate insecticides to three species of freshwater benthic invertebrates. Comp Biochem Physiol 110C: 149-155.

Relevance

Score: 92.5 (Control response)

Rating: R

Reliability

Score: 79

Rating: R

Notes: Using only data for chlorpyrifos only exposures; water quality information, test substance purity, replication, other information given as ranges for all tests and compounds; not possible to match specific data with each test.

Ankley & Collyard 1995		
Parameter	Value	Comment
Test method cited	None cited, but appears to follow EPA acute methods	Study by EPA staff
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	<i>Chironomus</i>	
Species	<i>tentans</i>	
Family resides in	North America	
Age/size at start of test/growth phase	Third instar	
Test duration	96 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Data for multiple times?	No	
Effect 1	Mortality/immobility	
Control response 1	NR	
Temperature	23 ± 1 °C	
Test type	Static	
Photoperiod	16L:8D	
Dilution water	Lake Superior water; as is, or with added hardness	

pH	7.4-8.5	
Hardness	42-47 mg/L as CaCO ₃	Hardness adjusted to 105 mg/L as CaCO ₃ , but not clear for which species in the study
Alkalinity	39-46 mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	5.2-8.1 mg/L	
Feeding	None	
Purity of test substance	≥ 95% pure	
Concentrations measured?	No	
Measured is what % of nominal?	NA	
Chemical method documented?	NA	
Concentration of carrier (if any) in test solutions	≤ 0.15 mL/L	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Control?	Methanol carrier at ≤ 1.5%	Reps: 2-4 w/5-10 per
LC50; indicate calculation method	0.47 ug/L (0.39-0.56, 95% C.I.)	Trimmed Spearman-Kärber

Reliability points taken off for:

Documentation: Analytical method (4), Nominal concentrations (3), Measured concentrations (3), Conductivity (2), Hypothesis tests (8)

Acceptability: Control response (9), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Conductivity (1), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Chironomus tentans

Study: Belden JB, Lydy MJ. 2000. Impact of atrazine on organophosphate insecticide toxicity. Environ Toxicol Chem 19: 2266-2274.

Relevance

Score: 92.5 (Control response NR)

Rating: R

Reliability

Score: 77.5

Rating: R

Notes: Study showed significant synergism between chlorpyrifos and atrazine. Only data for chlorpyrifos alone is shown here for use in criteria derivation, but synergism data is useful for consideration of mixtures.

Belden & Lydy 2000		
Parameter	Value	Comment
Test method cited	USEPA 1994	See full reference below
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	<i>Chironomus</i>	
Species	<i>tentans</i>	
Family resides in	North America	
Age/size at start of test/growth phase	4 th instar; 0.63-0.71 mm wide; ≥ 1.0 cm long	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Immobility + Mortality	
Control response 1	NR	
Temperature	20 \pm 1° C	
Test type	Static	
Photoperiod	16L:8D	
Dilution water	MHSFW	
pH	7.3-7.8	
Hardness	NR	
Alkalinity	NR	
Conductivity	320-350 uS/cm	

Belden & Lydy 2000		
Parameter	Value	Comment
Dissolved Oxygen	> 70%	
Feeding	NR	
Purity of test substance	> 98%	
Concentrations measured?	Yes	Nominal values used in calcs since measured values were w/in 10%
Measured is what % of nominal?	90%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR	
Concentration 1 Nom/Meas (µg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Concentration 2 Nom/Meas (µg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Concentration 3 Nom/Meas (µg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Concentration 4 Nom/Meas (µg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Concentration 5 Nom/Meas (µg/L)	NR; initial measured conc. w/in 10% of nominal; post-test values were 76-85% of initial values	Reps: 3 w/10 per
Control	Dilution water; solvent (acetone, 50 µL/L)	Reps: 3 w/10 per
ECx (95% C.I.); µg/L	EC1: 0.12 (0.08-0.17) EC5: 0.17 (0.12-0.22) EC15: 0.23 (0.18-0.28) EC50: 0.39 (0.33-0.45)	probit

USEPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminant with freshwater invertebrates. EPA/600/R-94/024. US Environmental Protection Agency, Washington, DC.

Reliability points taken off for:

Documentation: Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Hypothesis tests (8)

Acceptability: Control response (9), Carrier solvent ≤ 0.5 mL/L (4), Feeding (3), Hardness (2), Alkalinity (2), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Chironomus tentans

Study: Belden JB, Lydy MJ. 2006. Joint toxicity of chlorpyrifos and esfenvalerate to fathead minnows and midge larvae. Environ Toxicol Chem 25: 623-629.

Relevance

Score: 92.5 (Control not described)

Rating: R

Reliability

Score: 76.5

Rating: R

Belden & Lydy 2006		
Parameter	Value	Comment
Test method cited	USEPA 1994	Reference below
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	<i>Chironomus</i>	
Species	<i>tentans</i>	
Family resides in	North America	
Age/size at start of test/growth phase	3 rd -4 th instar larvae	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mobility	
Control response 1	< 10% mortality	
Temperature	21 ± 2° C	
Test type	Static	
Photoperiod/light intensity	NR	
Dilution water	Moderately hard synthetic (MHSFW)	
pH	7.8-8.3	
Hardness	MHSFW	
Alkalinity	MHSFW	
Conductivity	MHSFW	
Dissolved Oxygen	> 70%	
Feeding	NR	
Purity of test substance	> 98%	

Belden & Lydy 2006		
Parameter	Value	Comment
Concentrations measured?	No, but stability confirmed in separate study	
Measured is what % of nominal?	90% pre-test; 85% post-test	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None	
Concentration 1 Nom/Meas (µg/L)	NR	Reps and #: 3 w 10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps and #: 3 w 10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps and #: 3 w 10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps and #: 3 w 10 per
Concentration 5 Nom/Meas (µg/L)	NR	Reps and #: 3 w 10 per
Control	Not described; presumably dilution water	Reps and #: 3 w 10 per
ECx (95% C.I.)	EC10: 0.084 (0.052-0.108) ug/L EC50: 0.16 (0.13-0.19) ug/L	Log-probit

USEPA. 1994. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminant with freshwater invertebrates. EPA/600/R-94/024. US Environmental Protection Agency, Washington, DC.

Reliability points taken off for:

Documentation: Control type (8), Nominal concentrations (3), Measured concentrations (3), Photoperiod (3), Hypothesis tests (8)

Acceptability: Control appropriate (6), Carrier solvent ≤ 0.5 mL/L (4), Photoperiod (2), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Chironomus tentans

Study: Lydy MJ, Austin KR. 2004. Toxicity assessment of pesticide mixtures typical of the Sacramento-San Joaquin Delta using *Chironomus tentans*. Arch Environ Contam Toxicol 48: 49-55.

Relevance

Score: 100

Rating: R

Reliability

Score: 81.5

Rating: R

Lydy & Austin 2004		
Parameter	Value	Comment
Test method cited	EPA/600/R-94/024	USEPA 1994
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	<i>Chironomus</i>	
Species	<i>tentans</i>	
Family resides in	North America	
Age/size at start of test/growth phase	4 th instar	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Unable to perform figure 8 when prodded	
Control response 1	< 10%	
Temperature	21 ± 2°C	
Test type	Static	
Photoperiod/light intensity	16:8	
Dilution water	MHSFW	
pH	7.8-8.2	
Hardness	MH water	
Alkalinity	MH water	
Conductivity	320-360 uS/cm	
Dissolved Oxygen	> 75%	

Lydy & Austin 2004		
Parameter	Value	Comment
Feeding	None	
Purity of test substance	99.9%	
Concentrations measured?	Yes	
Measured is what % of nominal?	> 90%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	100 uL/L	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 3 w 10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 3 w 10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 3 w 10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 3 w 10 per
Concentration 5 Nom/Meas (µg/L)	NR	Reps: 3 w 10 per
Control	Solvent	Reps: 3 w 10 per
EC50 (95% C.I.); ug/L	0.17 (0.15-0.21)	Method NR

Reliability points taken off for:

Documentation: Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Statistical methods identified (5), Hypothesis tests (8)

Acceptability: Appropriate age/size (3), Organisms randomly assigned to containers (1), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Random or block design (2), Appropriate spacing between concentrations (2), Appropriate statistical method (2), Hypothesis tests (3)

Toxicity Data Summary

Chironomus tentans

Study: Pape-Lindstrom PA, Lydy MJ. 1997. Synergistic toxicity of atrazine and organophosphate insecticides contravenes the response addition mixture model. Environ Toxicol Chem 16: 2415-2420.

Relevance

Score: 100

Rating: R

Reliability

Score: 81

Rating: R

Notes: Exposure is in water with silica sand substrate; this type of sand has been shown not to affect bioavailability of Ops.

Pape-Lindstrom & Lydy 1997		
Parameter	Value	Comment
Test method cited	None cited for entire test, but parts of USEPA1991 (EPA-600-4-90-027) cited	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Chironomidae	
Genus	<i>Chironomus</i>	
Species	<i>tentans</i>	
Family resides in	North America	
Age/size at start of test/growth phase	Fourth instar	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Failure to execute 3 figure-8 motions when prodded	Effect linked to mortality
Control response 1	< 5% mortality	
Temperature	20 ± 1 °C	Mean ± sd
Test type	Static	
Photoperiod	16L:8D	
Dilution water	Moderately hard standard reference water (EPA)	

Pape-Lindstrom & Lydy 1997		
Parameter	Value	Comment
pH	7.95 ± 0.19	Mean ± sd
Hardness	NR; but meets EPA MHSFW specs	
Alkalinity	NR; but meets EPA MHSFW specs	
Conductivity	361 ± 10.3 uS/cm	Mean ± sd
Dissolved Oxygen	88.8 ± 7.1%	Mean ± sd
Feeding	None	
Purity of test substance	99%	
Concentrations measured?	No	
Measured is what % of nominal?	NA	
Chemical method documented?	NA	
Concentration of carrier (if any) in test solutions	0.5 mL/L	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 5 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Control	Dilution water and solvent (acetone @ 0.5 ml/L	Reps: 3 w/10 per
LC50 (95% C.I.)	Test 1: 0.58 ug/L (0.43-0.68); Test 2: 0.75 (0.58-0.99); Test 3: 0.51 (0.42-0.63)	probit

Reliability points taken off for:

Documentation: Analytical method (4), Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Hypothesis tests (8)

Acceptability: Acceptable standard method (5), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Daphnia ambigua

Study: Harmon SM, Specht WL, Chandler GT. 2003. A comparison of the daphnids *Ceriodaphnia dubia* and *Daphnia ambigua* for their utilization in routine toxicity testing in the Southeastern United States. Arch Environ Contamin Toxicol 45: 79-85.

Relevance

Score: 100

Rating: R

Reliability

Score: 87.5

Rating: R

Harmon et al. 2003		
Parameter	Value	Comment
Test method cited	ASTM E-729-88a	
Phylum/sub-phylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Daphnia</i>	
Species	<i>ambigua</i>	
Family resides in	North America	
Age/size at start of test/growth phase	Neonates	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Immobilization	
Control survival	Dilution water = 49/50 Solvent control = 50/50	
Temperature	21 ± 2 °C	
Test type	Static	
Photoperiod	16L:8L	
Dilution water	Moderately hard reconstituted water	
pH	8.11-8.66	
Hardness	54-72 mg/L as CaCO ₃	
Alkalinity	57-76 mg/L as CaCO ₃	
Conductivity	NR	

Harmon et al. 2003		
Parameter	Value	Comment
Dissolved Oxygen	7.46-9.14 mg/L	
Feeding	No	
Purity of test substance	Not stated; used research grade Dursban XP	
Concentrations measured?	Yes	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	37.5 uL/L	
Concentration 1 Meas (µg/L)	0.02	Reps: 5 w/10 per
Concentration 2 Meas (µg/L)	0.03	Reps: 5 w/10 per
Concentration 3 Meas (µg/L)	0.04	Reps: 5 w/10 per
Concentration 4 Meas (µg/L)	0.06	Reps: 5 w/10 per
Concentration 5 Meas (µg/L)	0.08	Reps: 5 w/10 per
Control?	Dilution water and solvent	Reps: 5 w/10 per; 37.5 uL/L methanol
LC50; indicate calculation method	0.035 ug/L (0.032-0.037)	Trimmed Spearman-Kärber; (95% C.I.)

Reliability points taken off for:

Documentation: Measured concentrations (3), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Daphnia magna

Study: Kersting K, Van Wijngaarden R. 1992. Effects of chlorpyrifos on a microecosystem. Environ Toxicol Chem 11: 365-372.

Relevance

Score: 90 (No Standard method)

Rating: R

Reliability

Score: Acute: 80, Chronic: 66.5

Rating: Acute: R, Chronic: L

Notes: This study includes a microecosystem component that did not produce any LC, EC or NOEC values. The information summarized here is only for the single-species components of this study.

Kersting & Van Wijngaarden 1992		
Parameter	Value	Comment
Test method cited	No standard method cited	
Phylum/subphylum	Arthropoda/Crustacea	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Daphnia</i>	
Species	<i>magna</i>	
Family resides in	North America	
Age/size at start of test/growth phase	Neonates < 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	Acute: 48 h Chronic: 21 d	
Data for multiple times?	Yes, for acute test	
Effect 1	Acute: Mortality Chronic: Mortality	
Control response 1	Acute: 0% Chronic: 0%	
Effect 2	Chronic: Reproduction	
Control response 2	51-58 neonates per female	
Temperature	NR for single-species tests, but 18 °C for microecosystem	Acc. To DF&G 19.5 °C

Kersting & Van Wijngaarden 1992		
Parameter	Value	Comment
Test type	Acute: static; Chronic: static-renewal (48-72-h renewal)	
Photoperiod	NR	
Dilution water	0.5 strength medium 63	From Taub & Dollar (1968)
pH	Acute: 6.8-7.0 Chronic: 7.0-8.1	
Hardness	NR	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	Acute: 7.7-8.8 mg/L Chronic: 8.8-9.9 mg/L	
Feeding	Acute: None Chronic: Yes	
Purity of test substance	NR, Acc. To DF&G 99%	
Concentrations measured?	Acute: Yes, highest 3 doses; reported as mean of concentration at 0 and 48 h; values of lower concentrations calculated assuming similar degradation; Chronic: apparently not measured; NOEC calculations based on nominal	
Measured is what % of nominal?	80-140%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR	
Concentration 1 Nom/Meas (µg/L)	0.01	Reps: NR w/25 per
Concentration 2 Nom/Meas (µg/L)	0.03	Reps: NR w/25 per
Concentration 3 Nom/Meas (µg/L)	0.1	Reps: NR w/25 per
Concentration 4 Nom/Meas (µg/L)	0.3	Reps: NR w/25 per
Concentration 5 Nom/Meas (µg/L)	1/0.8-1.4 (48 & 0 h in acute)	Reps: NR w/25 per
Concentration 6 Nom/Meas (µg/L)	3/2.4-3.1 (48 & 0 h in acute)	Reps: NR w/25 per
Concentration 7 Nom/Meas (µg/L)	10/8.0-10.4 (48 & 0 h in acute)	Reps: NR w/25 per
Control	Dilution water; solvent (acetone; amount not given)	Reps: NR w/25 per
LC50 (95% C.I.); ug/L	24-h LC50: 3.7 (2.5-5.9); 48-h LC50: 1.0 (1.0-1.1); 48-h LC25: 0.4	LC50: logit; LC25: graphical; Both based on mean of measured concentrations at 0 and 48 h.
NOEC; ug/L	Acute: 0.1;	Significant

Kersting & Van Wijngaarden 1992		
Parameter	Value	Comment
	Chronic Survival: 0.1; Chronic Repro.: 0.1	difference from control; method not stated; based on nominal
LOEC; indicate calculation method	Acute: 0.3 Chronic Survival: 0.3 Chronic Repro.: 0.3	
MATC (GeoMean NOEC,LOEC)	0.17 for all	
Difference from control at NOEC	Not calculable; data not given	
Difference from control at LOEC	Not calculable; data not given	

Taub FB, Dollar AM. 1968. The nutritional inadequacy of *Chlorella* and *Chlamydomonas* as food for *Daphnia pulex*. Limnol Oceanogr 13: 607-618.

Medium 63:

1.5 mM NaCl

1 mM CaCl₂

0.5 mM NaNO₃

0.42 mM NaHCO₃

0.1mM MgSO₄

0.08 mM Na₂(SiO₄)₃

0.04mM KH₂PO₄

Acute test

Reliability points taken off for:

Documentation: Hardness (2), Alkalinity (2), Conductivity (2), pH (3), Photoperiod (3), Hypothesis tests (8)

Acceptability: Acceptable standard method (5), Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Appropriate age/size (3), Organisms randomly assigned to containers (1), Conductivity (1), Photoperiod (2), Random or block design (2), Adequate replication (2), Hypothesis tests (3)

Chronic test

Reliability points taken off for:

Documentation: Analytical method (4), Exposure Type (5), Hardness (2), Alkalinity (2), Conductivity (2), Photoperiod (3), Statistical methods identified (5), Point estimates (8)

Acceptability: Acceptable standard method (5), Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Organisms randomly assigned to containers (1), Exposure type appropriate (2), Conductivity (1), Photoperiod (2), Random or block design (2), Adequate replication (2), LC/EC values (3)

Toxicity Data Summary

Daphnia magna

Burgess D. 1988. Acute flow through toxicity of chlorpyrifos to daphnia magna: final Report No. 37190. Unpublished study prepared by Analytical Biochemistry Laboratories, Inc 158 p. MRID 40840902

Relevance

Score: 100

Rating: R

Reliability

Score: 90

Rating: R

Burgess 1988		
Parameter	Value	Comment
Test method cited	EPA ASTM	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Daphnia</i>	
Species	<i>magna</i>	
Family in North America?	Yes	
Age/size at start of test/growth phase	First instar/ < 24hr	
Source of organisms	In house culture	
Have organisms been exposed to contaminants?	no	
Animals acclimated and disease-free?	Yes	
Animals randomized?	yes	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	24 and 48h	
Effect 1	mortality	
Control response 1	0%	
Temperature	18-21 C	
Test type	Flow thru	
Photoperiod/light intensity	16 h light / 50-70 Ftc	
Dilution water	RO and well water blend	
pH	7.9-8.1	
Hardness	160 – 180 mg/L	
Alkalinity	180 mg/L	
Conductivity	220 – 400 umhos/cm	
Dissolved Oxygen	8.0 -8.3 mg/L	
Feeding	No	
Purity of test substance	95.5 %	

Burgess 1988		
Parameter	Value	Comment
Concentrations measured?	Only the highest 2	
Measured is what % of nominal?	98 +/- 7.5%	
Chemical method documented?	Gas chromatography	
Concentration of carrier (if any) in test solutions	0.05ml/L acetone	
Concentration 1 Nom/Meas (µg/L)	0.012	4 Reps and 10 per rep
Concentration 2 Nom/Meas (µg/L)	0.024	4 Reps and 10 per rep
Concentration 3 Nom/Meas (µg/L)	0.05	4 Reps and 10 per rep
Concentration 4 Nom/Meas (µg/L)	0.10	4 Reps and 10 per rep
Concentration 5 Nom/Meas (µg/L)	0.20	4 Reps and 10 per rep
Control	solvent	4 Reps and 10 per rep
LC50; 48 hr	0.1 (0.09- 0.12) ug/L	probit

Reliability points taken off for:

Documentation: Measured concentrations (3), Hypothesis tests (8)

Acceptability: Dissolved Oxygen (6), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Daphnia pulex

Study: Van Der Hoeven N, Gerritsen AAM. 1997. Effects of chlorpyrifos on individuals and populations of *Daphnia pulex* in the laboratory and field. Environ Toxicol Chem 16: 2438-2447.

Rating: RR (only applies to study #2)

Relevance

Score: 90 (No standard method)

Rating: R

Reliability

Score: 78.5

Rating: R

Notes: Study includes 8 different experiments including acute, chronic, recovery scenarios, and population studies. Tests were as follows;

- 1) 2-d exposure, starting with neonates, using Dursban (45.3% active ingredient)
- 2) 2-d exposure, starting with neonates, using technical grade chlorpyrifos
- 3) 17-d exposure, starting with neonates, using Dursban
- 4) 6-d exposure, starting with neonates, using Dursban, with recovery period
- 5) 8-d exposure, starting with adults, using Dursban
- 6) 6-d exposure, starting with adults, using Dursban, with recovery period
- 7) 28-d field exposure of populations of mixed life stages
- 8) 28-d laboratory exposure of populations of mixed life stages

Van Der Hoeven & Gerritsen 1997		
Parameter	Value	Comment
Test method cited	No standard method cited	
Phylum	Arthropoda	
Class	Branchiopoda	
Order	Cladocera	
Family	Daphniidae	
Genus	<i>Daphnia</i>	
Species	<i>pulex</i>	
Family resides in	North America	
Age/size at start of test/growth phase	1) < 24 h 2) < 24 h 3) < 24 h 4) < 24 h 5) 7-8 d 6) 9-10 d 7) mixed 8) mixed	
Source of organisms	Lab culture	
Have organisms been exposed to	No	

Van Der Hoeven & Gerritsen 1997		
Parameter	Value	Comment
contaminants?		
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	1) 2 d 2) 2 d 3) 17 d 4) 1,2 or 3 d exposure; recovery through 6 d; 5) 8 d 6) 1,2 or 3 d exposure; recovery through 6 d 7) 28 d 8) 28 d	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	NR; 100% (from figure)	
Effect 2	Immobility	
Control response 2	NR	
Effect 3	Reproduction	
Control response 3	NR	
Effect 4	Population size	
Control response 4	NR	
Temperature	1-6,7) 20 ± 1 °C 8) 12-23 °C	
Test type	1) static 2) static 3) static-renewal; 3x per wk 4) static-renewal; 3x per wk 5) static-renewal; on days 1,2,3 6) static-renewal; on days 1,2,3 7,8) static-renewal; daily	
Photoperiod	Lab studies: 7 h D:1 h twilight; 15 h L: 1 h twilight; Field study: natural	
Dilution water	Lab studies: modified ground water	
pH	Lab: 8.0-8.2 Field: 7.5-9.5	
Hardness	Lab: 220 mg/L as CaCO ₃ ; Field: NR	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	NR	

Van Der Hoeven & Gerritsen 1997		
Parameter	Value	Comment
Feeding	For tests \leq 2d: none; For longer tests: daily	
Purity of test substance	45.% in tests with Dursban; NR for test (2) with technical grade	Technical compound accepted as being \geq 80% pure based on other reports of technical chlorpyrifos indicating that it is always \geq 80% pure.
Concentrations measured?	Yes	
Measured is what % of nominal?	33-99% laboratory; 30-52% field	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used with technical grade tests; NR in formulation tests	
Concentration range ($\mu\text{g/L}$); these are nominals; authors feel they are more reliable than the measured values; measured values as percentage of nominal ranged from 33-99% in laboratory studies; 30-52% in field.	1) 0.2-6.4; factor of 2; 2) 0.2-6.4; factor of 2; 3) 0.0125-0.4; factor of 2; 4) 0.05-1.6; factor of 2; 5) 0.2-0.64; factor of 1.8; 6) 0.4-1.6; factor of 2; 7) 0.1 and 0.7 $\mu\text{g/L}$; 8) 0.11, 0.17, 0.24, 0.33, 0.47, 0.66 $\mu\text{g/L}$	Reps: 1) 13-18 w/1 per 2) 13-19 w/1 per 3) 17-19 w/1 per 4) 19-20 w/1 per 5) 2 w/20 per 6) 2 w/14 per 7) 2 w/ 2 populations per 8) 2 w/1 per
Control	Dilution water and emulsifier controls	Reps: 1) 20 w/1 per 2) 20 w/1 per 3) 17 w/1 per 4) 20 w/1 per 5) 4 w/20 per 6) 4 w/14 per 7) 4 w/2 populations per 8) 4 w/1 per
LC50; indicate calculation method	Tech grade test: 24 h: 4.9 $\mu\text{g/L}$ 48 h: 0.42 $\mu\text{g/L}$	Maximum likelihood
ECx; indicate calculation method	Tech grade test: 24 h: 0.3 $\mu\text{g/L}$ 48 h: 0.25 $\mu\text{g/L}$ tables	Maximum likelihood
NOEC; indicate calculation method	1) $< 0.2 \mu\text{g/L}$	Dunnett's;

Van Der Hoeven & Gerritsen 1997		
Parameter	Value	Comment
	2) < 0.2 ug/L 3) 0.1 ug/L 4) 0.36 ug/L 5) 0.2 ug/L 6) < 0.4 ug/L 7) 0.052 ug/L 8) 0.17 ug/L	1,2) mortality, mobility; 3) mortality, mobility, reproduction; 4) mortality, mobility, length; 5,6) mortality, mobility, reproduction 7,8) population size
LOEC; indicate calculation method	1) 0.2 ug/L 2) 0.2 ug/L 3) 0.2 ug/L 4) 0.64 ug/L 5) 0.4 ug/L 6) 0.46ug/L 7) 0.26 ug/L 8) 0.24 ug/L	Dunnett's
MATC (GeoMean NOEC,LOEC)	1) NC 2) NC 3) 0.14 ug/L 4) 0.48 ug/L 5) 0.28 ug/L 6) NC 7) 0.12 ug/L 8) 0.20 ug/L	
Difference from control at NOEC	NC	
Difference from control at LOEC	NC	

Notes: Only test 2 was done with technical grade chlorpyrifos; it is the only test that can be used for criteria derivation. Reliability points taken off for:

Documentation: Measured concentrations (3), Alkalinity (2), Dissolved Oxygen (4), Conductivity (2), Hypothesis tests (8)

Acceptability: Acceptable standard method (5), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Alkalinity (2), Dissolved Oxygen (6), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Hyaella azteca

Study: Anderson TD, Lydy MJ. 2002. Increased toxicity to invertebrates associated with a mixture of atrazine and organophosphate insecticides. Environ Toxicol Chem 21: 1507-1514.

Relevance

Score: 92.5 (Control response NR)

Rating: R

Reliability

Score: 77

Rating: R

Anderson & Lydy 2002		
Parameter	Value	Comment
Test method cited	EPA -600-R-94-024	USEPA 1994
Phylum	Arthropoda	
Class	Malacostraca	
Order	Amphipoda	
Family	Hyaellidae	
Genus	<i>Hyaella</i>	
Species	<i>azteca</i>	
Family resides in	N. America	
Age/size at start of test/growth phase	14-21 d	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	NR	
Temperature	20 ± 1°C	
Test type	Static	
Photoperiod/light intensity	16:8	
Dilution water	NR	
pH	7.3-7.5	
Hardness	NR	
Alkalinity	NR	
Conductivity	331-359 uS/cm	
Dissolved Oxygen	≥ 81%	
Feeding	None	

Anderson & Lydy 2002		
Parameter	Value	Comment
Purity of test substance	≥ 98%	
Concentrations measured?	Yes	
Measured is what % of nominal?	≥ 90%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	100 uL per test vessel; size of vessel NR	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Concentration 5 Nom/Meas (µg/L)	NR	Reps: 3 w/10 per
Control	Solvent	Reps: 3 w/10 per
LC50 (95% C.I.)	0.0427 (0.0333-0.0492)	Log-probit

Reliability points taken off for:

Documentation: Nominal concentrations (3), Measured concentrations (3), dilution water source (3), Hardness (2), Alkalinity (2), Hypothesis tests (8)

Acceptability: Control response (9), Carrier solvent ≤ 0.5 mL/L (4), Dilution water source (2), Hardness (2), Alkalinity (2), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Hyaella azteca

Study: Ankley GT, Collyard SA. 1995. Influence of piperonyl butoxide on the toxicity of organophosphate insecticides to three species of freshwater benthic invertebrates. Comp Biochem Physiol 110C: 149-155.

Relevance

Score: 92.5 (Control response NR)

Rating: R

Reliability

Score: 77.5

Rating: R

Notes: Using only data for chlorpyrifos only exposures; water quality information, test substance purity, replication, other information given as ranges for all tests and compounds; not possible to match specific data with each test.

Ankley & Collyard 1995		
Parameter	Value	Comment
Test method cited	None cited, but appears to follow EPA acute methods	Study by EPA staff
Phylum	Arthropoda	
Class	Malacostraca	
Order	Amphipoda	
Family	Hyaellidae	
Genus	<i>Hyaella</i>	
Species	<i>azteca</i>	
Family resides in	North America	
Age/size at start of test/growth phase	7-14 d juveniles	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality/immobility	
Control response 1	NR	
Temperature	23 ± 1 °C	
Test type	Static	
Photoperiod	16L:8D	
Dilution water	Lake Superior water; as is, or with added hardness	

pH	7.4-8.5	
Hardness	42-47 mg/L as CaCO ₃	Hardness adjusted to 105 mg/L as CaCO ₃ , but not clear for which species in the study
Alkalinity	39-46 mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	5.2-8.1 mg/L	
Feeding	Yeast-Cerophyll-Trout Chow at test start	
Purity of test substance	≥ 95% pure	
Concentrations measured?	No	
Measured is what % of nominal?	NA	
Chemical method documented?	NA	
Concentration of carrier (if any) in test solutions	≤ 0.15 mL/L	
Concentration 1 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps: 2-4 w/5-10 per
Control?	Methanol carrier at ≤ 1.5%	Reps: 2-4 w/5-10 per
LC50; indicate calculation method	0.04 ug/L (0.03-0.05, 95% C.I.)	Trimmed Spearman-Kärber

Reliability points taken off for:

Documentation: Analytical method (4), Nominal concentrations (3), Measured concentrations (3), Conductivity (2), Hypothesis tests (8)

Acceptability: Control response (9), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Feeding (3) Conductivity (1), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Hyalella azteca

Brown R, Hugo J, Miller J, Harrington C. 1997 Chlorpyrifos acute toxicity to the amphipod *Hyalella azteca*. Lab project No. 971095: 91/414 ANNEX I 8.3.4 Unpublished study prepared by the Dow Chemical Co. 27p. MRID 44345601.

Relevance

Score: 100

Rating: R

Reliability

Score: 92.5

Rating: R

Brown et al 1997		
Parameter	Value	Comment
Test method cited	EPA OPP 850.1020	
Phylum	Arthropoda	
Class	Crustacea	
Order	Malacostraca	
Family	Hyalellidae	
Genus	<i>Hyalella</i>	
Species	<i>azteca</i>	
Family in North America?	Yes	
Age/size at start of test/growth phase	14- 21 days	
Source of organisms	Aquatic biosystems Fort Collins CO	
Have organisms been exposed to contaminants?	NR	
Animals acclimated and disease-free?	NR	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	96 hr	
Data for multiple times?	Yes	
Effect 1	lethality	
Control response 1	7.5%	
Temperature	18.6 +/- 1 C	
Test type	Static Renewal	
Photoperiod/light intensity	16:8 light:dark	
Dilution water	Lake Huron water limed and flocculated, sand filtered, pH adjusted, carbon filtered, UV irradiated.	
pH	7.6	
Hardness	166 mg/L	
Alkalinity	36 mg/L	

Brown et al 1997		
Parameter	Value	Comment
Conductivity	760 umhos/cm	
Dissolved Oxygen	8.6-9.4 mg/L	
Feeding	No	
Purity of test substance	98.1%	
Concentrations measured?	Yes	
Measured is what % of nominal?	80-125%	
Chemical method documented?	Gas chromatography	
Concentration of carrier (if any) in test solutions	0.1mL/L Dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	25 / 32.1	2Reps and 10 per
Concentration 2 Nom/Meas (µg/L)	50 / 52.0	Reps and # per (cell density for single
Concentration 3 Nom/Meas (µg/L)	100/ 97.6	Reps and # per (cell density for single
Concentration 4 Nom/Meas (µg/L)	200 / 176	Reps and # per (cell density for single
Concentration 5 Nom/Meas (µg/L)	400 / 340	Reps and # per (cell density for single
Concentration 6 Nom/Meas (µg/L)	800 / 629	
Control		Reps and # per (cell density for single
LC50; indicate calculation method	0.138 ug/L	Moving average

Reliability points taken off for:

Documentation: Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Hypothesis tests (3)

Toxicity Data Summary

Ictalurus punctatus

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Relevance

Score: 100

Rating: R

Reliability

Score: 91.5

Rating: R

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	Value	Comment
Test method cited	New multispecies method based on ASTM, EPA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Siluriformes	
Family	Ictaluridae	
Genus	<i>Ictalurus</i>	
Species	<i>punctatus</i>	
Family resides in	North America	
Age/size at start of test/growth phase	7.9 g	
Source of organisms	Fish hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 ± 0.6 °C	
Test type	Flow-through	90% replacement in 8 h; 130 ml/min
Photoperiod	16L:8D	
Dilution water	Lake Superior	

Phipps & Holcombe 1985		
Parameter	Value	Comment
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as CaCO ₃	
Alkalinity	45.4 (range 42.3-57.0) mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	7.5 ± 1.6 mg/L (range 4.7-10.0); ≥ 50% saturation	mean ± sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Control?	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 20 per
L50 (95% C.I.)	96-h: 0.806 (0.434-1.088) mg/L 72-h: 0.806 mg/L	Trimmed Spearman-Kärber

Reliability points taken off for:

Documentation: Conductivity (2), Hypothesis tests (8)

Acceptability: Organisms randomly assigned to containers (1), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Lepomis macrochirus

Bowman J. 1988. Acute flow through toxicity of chlorpyrifos to bluegill sunfish (*Lepomis macrochirus*): project ID 37189. Unpublished study prepared by Analytical Biochemistry Laboratories, Inc 174 p. MRID 40840904

Relevance

Score: 100

Rating: R

Reliability

Score: 90.5

Rating: R

Reference		
Parameter	Value	Comment
Test method cited	EPA	
Phylum	Chordata	
Class	Actinopterygii	
Order	Perciformes	
Family	Centrarchidae	
Genus	<i>Lepomis</i>	
Species	<i>macrochirus</i>	
Family in North America?	Yes	
Age/size at start of test/growth phase	2.1 g, 41 mm	
Source of organisms	Osage catfisheries, MI	
Have organisms been exposed to contaminants?	Probably not	
Animals acclimated and disease-free?	yes	
Animals randomized?	Yes	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	24, 48, 72, 96 h	
Effect 1	Mortality	
Control response 1	0%	
Effect 2	Measured other effects, curved spine loss of equilibrium, etc., but didn't determine EC with them	
Control response 2	Most of those effects not observed in control	
Temperature	22 C	
Test type	Flow thru	
Photoperiod/light intensity	16 h light	
Dilution water	Ro well water blend	
pH	7.4 -7.7	
Hardness	40 -48 mg/L	Low?

Reference		
Parameter	Value	Comment
Alkalinity	44-56 mg/L	
Conductivity	100-160 umhos/cm	
Dissolved Oxygen	7.4 -8.4	
Feeding	No	
Purity of test substance	95.5	
Concentrations measured?	Yes	
Measured is what % of nominal?	84 +/- 5.6 %	
Chemical method documented?	GC ECD	
Concentration of carrier (if any) in test solutions	0.03 mL - not clear what is meant	
Concentration 1 Nom/Meas (µg/L)	20/ 18	1 Rep and 20 per
Concentration 2 Nom/Meas (µg/L)	10/ 8.7	1 Rep and 20 per
Concentration 3 Nom/Meas (µg/L)	5.0/ 3.8	1 Rep and 20 per
Concentration 4 Nom/Meas (µg/L)	2.5/ 2.0	1 Rep and 20 per
Concentration 5 Nom/Meas (µg/L)	1.3/ 1.1	1 Rep and 20 per
Control	Solvent and water only	1 Rep and 20 per
LC50; 96 h	5.8 (4/7 – 7.5) ug/L	Moving average

Other notes: Table 5 in report contains other effects like loss of equilibrium and labored breathing that were not included in the LC₅₀.

Reliability points taken off for:

Documentation: Hypothesis tests (8)

Acceptability: Carrier solvent ≤ 0.5 mL/L (4), Random or block design (2), Adequate replication (2), Hypothesis tests (3)

Toxicity Data Summary

Lepomis macrochirus

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Relevance

Score: 100

Rating: R

Reliability

Score: 91.5

Rating: R

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	Value	Comment
Test method cited	New multispecies method based on ASTM, EPA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Perciformes	
Family	Centrarchidae	
Genus	<i>Lepomis</i>	
Species	<i>macrochirus</i>	
Family resides in	North America	
Age/size at start of test/growth phase	0.8 g	
Source of organisms	Fish hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 ± 0.6 °C	
Test type	Flow-through	90% replacement in 8 h; 130 ml/min

Phipps & Holcombe 1985		
Parameter	Value	Comment
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as CaCO ₃	
Alkalinity	45.4 (range 42.3-57.0) mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	7.5 ± 1.6 mg/L (range 4.7-10.0); ≥ 50% saturation	mean ± sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Control	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 20 per
LC50 (95% C.I.)	96-h: 0.010 (0.006-0.014) mg/L	Trimmed Spearman-Kärber

Reliability points taken off for:

Documentation: Conductivity (2), Hypothesis tests (8)

Acceptability: Organisms randomly assigned to containers (1), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Neomysis mercedis

Study: CDFG. 1992a. Test No. 133. 96-h acute toxicity of chlorpyrifos to *Neomysis mercedis*, Aquatic Toxicity Laboratory, Elk Grove, CA.

Relevance

Score: 100

Rating: R

Reliability

Score: 89

Rating: R

CDFG 1992a		
Parameter	Value	Comment
Test method cited	ASTM 1988 (E729-88)	
Phylum/subphylum	Arthropoda/Crustacea	
Class	Malacostraca	
Order	Mysidacea	
Family	Mysidae	
Genus	<i>Neomysis</i>	
Species	<i>mercedis</i>	
Family resides in	N. Amer.	
Age/size at start of test/growth phase	< 5 d post-release	
Source of organisms	Lab cultures	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	Dilution water: 0% Solvent: 5% Total: 2.5%	
Temperature; mean	17.2° C	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water plus 2 g/kg artificial sea salt	
pH; mean	8.39	
Hardness; mean	499 mg/L as CaCO ₃	
Alkalinity; mean	154 mg/L as CaCO ₃	

CDFG 1992a		
Parameter	Value	Comment
Conductivity; mean	3076 uS/cm	
Dissolved Oxygen; mean	8.41 mg/L	
Feeding	Artemia nauplii; frequency NR	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	124%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	0.026 mL/L	
Concentration 1 Meas (µg/L)	0.065	Reps: 20 w/1 per
Concentration 2 Meas (µg/L)	0.14	Reps: 20 w/1 per
Concentration 3 Meas (µg/L)	0.305	Reps: 20 w/1 per
Concentration 4 Meas (µg/L)	0.61	Reps: 20 w/1 per
Concentration 5 Meas (µg/L)	1.3	Reps: 20 w/1 per
Control	< 0.03 ug/L chlorpyrifos; dilution water; solvent (triethylene glycol, triethylene glycol dimethyl ether, ≤ 0.026 mL/L)	Reps: 20 w/1 per
LC50 (95% C.I.); ug/L	0.16 (0.14-0.30)	Non-linear interpolation
NOEC; ug/L	0.065	Chi squared
LOEC; ug/L	0.14	
MATC (GeoMean NOEC,LOEC)	0.095	
% of control at NOEC	105%	Based on solvent control
% of control at LOEC	68%	Based on solvent control

Reliability points taken off for:

Documentation: Nominal concentrations (3), Statistical significance level (2), MSD (2)

Acceptability: Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Feeding (3), Organisms properly acclimated/disease free (1), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Random or block design (2), MSD (1)

Toxicity Data Summary

Neomysis mercedis

Study: CDFG. 1992d. Test No. 142. 96-h acute toxicity of chlorpyrifos to *Neomysis mercedis*, Aquatic Toxicity Laboratory, Elk Grove, CA.

Relevance

Score: 100

Rating: R

Reliability

Score: 89

Rating: R

CDFG 1992d		
Parameter	Value	Comment
Test method cited	ASTM 1988 (E729-88)	
Phylum/subphylum	Arthropoda/Crustacea	
Class	Malacostraca	
Order	Mysidacea	
Family	Mysidae	
Genus	<i>Neomysis</i>	
Species	<i>mercedis</i>	
Family resides in	N. Amer.	
Age/size at start of test/growth phase	< 5 d post-release	
Source of organisms	Lab cultures	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	0%	
Temperature; mean	17.1° C	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water plus 2 g/kg artificial sea salt	
pH; mean	8.36	
Hardness; mean	509 mg/L as CaCO ₃	
Alkalinity; mean	151 mg/L as CaCO ₃	

CDFG 1992d		
Parameter	Value	Comment
Conductivity; mean	3151 uS/cm	
Dissolved Oxygen; mean	9.26 mg/L	
Feeding	Artemia nauplii; frequency NR	
Purity of test substance	99%	
Concentrations measured?	Yes	
Concentration 1 Meas (µg/L)	0.045	Reps: 20 w/1 per
Concentration 2 Meas (µg/L)	0.09	Reps: 20 w/1 per
Concentration 3 Meas (µg/L)	0.18	Reps: 20 w/1 per
Concentration 4 Meas (µg/L)	0.365	Reps: 20 w/1 per
Concentration 5 Meas (µg/L)	0.77	Reps: 20 w/1 per
Control	< 0.03 ug/L chlorpyrifos; dilution water; solvent (triethylene glycol, triethylene glycol dimethyl ether, ≤ 0.026 mL/L)	Reps: 20 w/1 per
Measured is what % of nominal?	73%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	0.026 mL/L	
LC50 (95% C.I.); ug/L	0.14 (0.09-0.18)	Non-linear interpolation
NOEC; ug/L	0.09	Chi squared
LOEC; ug/L	0.18	
MATC (GeoMean NOEC,LOEC)	0.13	
% of control at NOEC	100%	
% of control at LOEC	15%	

Reliability points taken off for:

Documentation: Nominal concentrations (3), Statistical significance level (2), MSD (2)

Acceptability: Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Feeding (3), Organisms properly acclimated/disease free (1), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Random or block design (2), MSD (1)

Toxicity Data Summary

Neomysis mercedis

Study: CDFG. 1992e. Test No. 143. 96-h acute toxicity of chlorpyrifos to *Neomysis mercedis*, Aquatic Toxicity Laboratory, Elk Grove, CA.

Relevance

Score: 100

Rating: R

Reliability

Score: 89

Rating: R

CDFG 1992e		
Parameter	Value	Comment
Test method cited	ASTM 1988 (E729-88)	
Phylum/subphylum	Arthropoda/Crustacea	
Class	Malacostraca	
Order	Mysidacea	
Family	Mysidae	
Genus	<i>Neomysis</i>	
Species	<i>mercedis</i>	
Family resides in	N. Amer.	
Age/size at start of test/growth phase	< 5 d post-release	
Source of organisms	Lab cultures	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes; see study	
Effect 1	Mortality	
Control response 1	0%	
Temperature; mean	17.4° C	
Test type	Static renewal; daily renewal	
Photoperiod	16L:8D	
Dilution water	Aquat Tox Lab well water plus 2 g/kg artificial sea salt	
pH; mean	8.21	
Hardness; mean	515 mg/L as CaCO ₃	
Alkalinity; mean	152 mg/L as CaCO ₃	
Conductivity; mean	3192 uS/cm	
Dissolved Oxygen; mean	8.90 mg/L	

Feeding	Artemia nauplii; frequency NR	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	72%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	0.026 mL/L	
Concentration 1 Meas (µg/L)	0.045	Reps: 20 w/1 per
Concentration 2 Meas (µg/L)	0.09	Reps: 20 w/1 per
Concentration 3 Meas (µg/L)	0.18	Reps: 20 w/1 per
Concentration 4 Meas (µg/L)	0.365	Reps: 20 w/1 per
Concentration 5 Meas (µg/L)	0.755	Reps: 20 w/1 per
Control	< 0.03 µg/L chlorpyrifos; dilution water; solvent (triethylene glycol, triethylene glycol dimethyl ether, ≤ 0.026 mL/L)	Reps: 20 w/1 per
LC50 (95% C.I.); µg/L	0.15 (0.09-0.1825)	Non-linear interpolation
NOEC; µg/L	0.09	Chi squared
LOEC; µg/L	0.18	
MATC (GeoMean NOEC,LOEC)	0.13	
% of control at NOEC	100%	
% of control at LOEC	30%	

Reliability points taken off for:

Documentation: Nominal concentrations (3), Statistical significance level (2), MSD (2)

Acceptability: Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Feeding (3), Organisms properly acclimated/disease free (1), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Random or block design (2), MSD (1)

Toxicity Data Summary

Oncorhynchus mykiss (formerly *Salmo gairdneri*)

Bowman J. 1988. Acute flow through toxicity of chlorpyrifos to rainbow trout (*Salmo gairdneri*): project ID 37188. Unpublished study prepared by Analytical Biochemistry Laboratories, Inc 174 p. MRID 40840903

Relevance

Score: 100

Rating: R

Reliability

Score: 91.5

Rating: R

Reference		
Parameter	Value	Comment
Test method cited	EPA	
Phylum	Chordata	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	<i>Oncorhynchus</i>	
Species	<i>mykiss</i>	
Family in North America?	Yes	
Age/size at start of test/growth phase	0.25g /3.9mm	
Source of organisms	Mt Lassen trout farm CA	
Have organisms been exposed to contaminants?	Probably not	
Animals acclimated and disease-free?	yes	
Animals randomized?	yes	
Test vessels randomized?		
Test duration	96 h	
Data for multiple times?	Yes 24,48,72, 96	
Effect 1	Mortality	
Control response 1	0%	
Effect 2	Measured other effects, curved spine loss of equilibrium, etc., but didn't determine EC with them	
Control response 2	Most of those effects not observed in control	
Temperature	12 +/- 1 C	
Test type	Flow thru	
Photoperiod/light intensity	16 h light	
Dilution water	RO well water mix	
pH	7.6-7.8	

Reference		
Parameter	Value	Comment
Hardness	40-48 mg/L	Low
Alkalinity	44-56 mg/L	
Conductivity	100-160 umhos/cm	
Dissolved Oxygen	8.5- 9.2	
Feeding	No	
Purity of test substance	95.9	
Concentrations measured?	Yes	
Measured is what % of nominal?	86 +/- 75.7%	
Chemical method documented?	Yes- GC/ ECD	
Concentration of carrier (if any) in test solutions	0.1mL/L	
Concentration 1 Nom/Meas (µg/L)	5.0/ 4.2	1 Reps and 20 per
Concentration 2 Nom/Meas (µg/L)	10 /8.1	1 Reps and 20 per
Concentration 3 Nom/Meas (µg/L)	20/ 16	1 Reps and 20 per
Concentration 4 Nom/Meas (µg/L)	40/ 37	1 Reps and 20 per
Concentration 5 Nom/Meas (µg/L)	80/ 72	1 Reps and 20 per
Control	Solvent and water only	
LC50; 96h	25 (20-32) ug/L	Moving average

Other notes: Table 5 in report contains other effects like loss of equilibrium and labored breathing that weren't included in the LC50.

Reliability points taken off for:

Documentation: Hypothesis tests (8)

Acceptability: Random or block design (2), Adequate replication (2), Hypothesis tests (3)

Toxicity Data Summary

Oncorhynchus mykiss

Study: Holcombe GW, Phipps GL, Tanner DK. 1982. The acute toxicity of kelthane, dursban, disulfoton, pydirn, and permethrin to fathead minnows *Pimephales promelas* and rainbow trout *Salmo gairdneri*. Environ Poll (Series A) 29: 167-178.

Relevance

Score: 92.5 (Control response NR)

Rating: R

Reliability

Score: 80.5

Rating: R

Notes: 24-, 48-, 72- and 96-h LC50s reported

Holcombe et al. 1982		
Parameter	Value	Comment
Test method cited	USEPA 1975	Cited for “procedures and methods not specified” in text
Phylum	Chordata	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	<i>Oncorhynchus</i>	
Species	<i>mykiss</i>	
Family resides in	North America	
Age/size at start of test/growth phase	Juvenile; 1.0 g	
Source of organisms	Hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	Yes, but not raw data	
Effect 1	Mortality	
Control response 1	NR	
Effect 2	Equilibrium	No statistical analysis
Effect 3	Coloration	No statistical analysis
Effect 4	Deformities	No statistical analysis
Temperature	12 °C	
Test type	Flow-through	

Holcombe et al. 1982		
Parameter	Value	Comment
Photoperiod	16L:8D	
Dilution water	Lake Superior water	
pH	7.0-7.4	
Hardness	45.3 (43.7-46.5) mg/L as CaCO ₃	
Alkalinity	41.8 (39.6-43.2) mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	9.3 (7.5-11.3) mg/L	
Feeding	Not fed from 24 h before nor through test	
Purity of test substance	99.9%	
Concentrations measured?	Yes; nominal concentrations not given	
Measured is what % of nominal?	92.7%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Nom/Meas (µg/L)	1.5 ± 0.1	Reps: 2 (10 per tank)
Concentration 2 Nom/Meas (µg/L)	2.7 ± 0.3	Reps: 2 (10 per tank)
Concentration 3 Nom/Meas (µg/L)	5.0 ± 0.4	Reps: 2 (10 per tank)
Concentration 4 Nom/Meas (µg/L)	7.7 ± 0.6	Reps: 2 (10 per tank)
Concentration 5 Nom/Meas (µg/L)	17.0 ± 2.0	Reps: 2 (10 per tank)
Number of controls	1 with 2 reps (10 per tank)	No carrier used
LCx; indicate calculation method	24-h LC50 = > 17.0 ± 2.0; 48-h LC50 = 11.4 (10.8-12.2); 72-h LC50 = 8.0 (6.8-9.4); 96-h LC50 = 8.0 (6.8-9.4)	Replicates combined; Trimmed Spearman Karber; value (95% C.I.) ug/L

Deformities after 30 h to ≥ 5.0 ug/L.

USEPA. 1975. The committee on methods for toxicity tests with aquatic organisms. Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians. EPA-660/3-75-009, Duluth MN

Reliability points taken off for:

Documentation: Nominal concentrations (3), Conductivity (2), Hypothesis tests (8)

Acceptability: Control appropriate (6), Control response (9), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated/disease free (1), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Oncorhynchus mykiss

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Relevance

Score: 100

Rating: R

Reliability

Score: 91.5

Rating: R

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	Value	Comment
Test method cited	New multispecies method based on ASTM, EPA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	<i>Oncorhynchus</i>	
Species	<i>mykiss</i>	
Family resides in	North America	
Age/size at start of test/growth phase	3.0 g	
Source of organisms	Hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 ± 0.6 °C	

Phipps & Holcombe 1985		
Parameter	Value	Comment
Test type	Flow-through	90% replacement in 8 h; 130 ml/min
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as CaCO ₃	
Alkalinity	45.4 (range 42.3-57.0) mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	7.5 ± 1.6 mg/L (range 4.7-10.0); ≥ 50% saturation	mean ± sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Control?	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 20 per
LC50 (95% C.I.)	96-h: 0.009 (0.007-0.011) mg/L	Trimmed Spearman-Kärber

Reliability points taken off for:

Documentation: Conductivity (2), Hypothesis tests (8)

Acceptability: Organisms randomly assigned to containers (1), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Oncorhynchus tshawytscha

Study: Wheelock CE, Eder KJ, Werner I, Huang H, Jones PD, Brammell BF, Elskus AA, Hammock BD. 2005. Individual variability in esterase activity and CYP1A levels in Chinook salmon (*Oncorhynchus tshawytscha*) exposed to esfenvalerate and chlorpyrifos. *Aquat Toxicol* 74: 172-192.

Relevance: Mortality

Score: 90 (No standard method)

Rating: R

Reliability

Score: 84.5

Rating: R

Relevance: Chronic, AchE inhibition

Score: 75 (No standard method, Endpoint)

Wheelock et al. 2005		
Parameter	Value	Comment
Test method cited	None cited	
Phylum	Chordata	
Class	Actinopterygii	
Order	Salmoniformes	
Family	Salmonidae	
Genus	<i>Oncorhynchus</i>	
Species	<i>tshawytscha</i>	
Family resides in	North America	
Age/size at start of test/growth phase	Juvenile	
Test duration	96 h	
Source of organisms	Hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Data for multiple times?	No	
Effect 1	Mortality	No stats on mortality data
Control response 1	0%	
Effect 2	Acetylcholinesterase activity	
Control response 2		
Effect 3	Carboxylesterase activity	
Control response 3	CYP1A (P450) levels	

Wheelock et al. 2005		
Parameter	Value	Comment
Temperature	14.8 ± 0.5 °C	
Test type	Static renewal; 75% replacement every 24 h	Soda-lime flint glass containers
Photoperiod	16L:8D	
Dilution water	Not stated, but appears to be well water	
pH	8.4 ± 0.2	
Hardness	NR	
Alkalinity	NR	
Conductivity	680 ± 50 uS/cm	
Dissolved Oxygen	9.1 ± 0.8 mg/L	
Feeding	Not fed one day prior nor through the test	
Purity of test substance	99.5%	
Concentrations measured?	Yes	
Measured is what % of nominal?	Yes	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	50 uL/4L	
Concentration 1 Nom/Meas (µg/L)	1.0/1.2	Reps: 10 (1 fish ea)
Concentration 2 Nom/Meas (µg/L)	10/7.3	Reps: 10 (1 fish ea)
Concentration 3 Nom/Meas (µg/L)	100/81	Reps: 10 (1 fish ea)
Control?	Yes with 50ul MeOH/L	Reps: 10 (1 fish a)
LCx; indicate calculation method	Not calculated in original study; see below	
ECx; indicate calculation method	See below	
NOEC; indicate calculation method	See below	
LOEC; indicate calculation method	See below	
MATC (GeoMean NOEC, LOEC)		
Difference from control at NOEC	See below	
Difference from control at LOEC	See below	

Mortality

0% in control

0% at 1.2 µg/L

20% at 7.3 µg/L

100% at 81 µg/L

Linear regression equation for rough LC_{7.5}, LC₁₀, LC_{17.5}, LC₂₀, calculations (Excel v 11.2.5)

$$\ln(\text{number surviving}) = -0.0285 (\text{concentration, } \mu\text{L}) + 2.3096$$

LC_{7.5} = 3.0
LC₁₀ = 3.9
LC_{18.2} = 7.3
LC₂₀ = 8.1
LC₅₀ = 24.6

For criteria calculation: LC₅₀ by trimmed Spearman-Kärber: 15.96 (9.37-27.19) µ/L

NOEC: Acetylcholinesterase activity

Chlorpyrifos (brain): 1.2 ug/L (92% of solvent control)
Chlorpyrifos (muscle): 1.2 ug/L (111% of solvent control)

LOEC: AChE activity

Brain: 7.3 ug/L (15% of control)
Muscle: 7.3 ug/L (8% of control)

NOECs: carboxylesterase activity (liver)

Substrate PNPA: < 1.2 ug/L
Substrate Acetate: 1.2 ug/L (115% of solvent control)
Substrate Butyrate: 1.2 ug/L (84% of solvent control)

LOECs: carboxylesterase activity (liver)

Substrate PNPA: 1.2 ug/L (44% of solvent control)
Substrate Acetate: 7.3 ug/L (48% of control)
Substrate Butyrate: 7.3 ug/L (45% of control)

NOEC: CYP1A levels

1.2 ug/L (95% of solvent control)

LOEC: CYP1A levels

7.3 ug/L (72% of solvent control)

Reliability points taken off for:

Documentation: Dilution water source (3), Hardness (2), Alkalinity (2), MSD (2)

Acceptability: Acceptable standard method (5), Adequate number per replicate (2), Feeding (3), Organisms properly acclimated/disease free (1), Dilution water source (2), Hardness (2), Alkalinity (2), Adequate number of concentrations (3), Random or block design (2), Appropriate spacing between concentrations (2), MSD (1)

Toxicity Data Summary

Orconectes immunis

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Relevance

Score: 100

Rating: R

Reliability

Score: 91.5

Rating: R

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	Value	Comment
Test method cited	New multispecies method based on ASTM, EPA methods	
Phylum	Arthropoda	
Class	Malacostraca	
Order	Decapoda	
Family	Cambaridae	
Genus	<i>Orconectes</i>	
Species	<i>immunis</i>	
Family resides in	North America	
Age/size at start of test/growth phase	1.8 g	
Source of organisms	Hatchery	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 ± 0.6 °C	
Test type	Flow-through	90% replacement in 8 h; 130 ml/min

Phipps & Holcombe 1985		
Parameter	Value	Comment
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as CaCO ₃	
Alkalinity	45.4 (range 42.3-57.0) mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	7.5 ± 1.6 mg/L (range 4.7-10.0); ≥ 50% saturation	mean ± sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/10 per
Control?	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 10 per
LC50 (95% C.I.)	96-h: 0.006 (0.004-0.009) mg/L	Trimmed Spearman-Kärber

Reliability points taken off for:

Documentation: Nominal Concentrations (3), Conductivity (2), Hypothesis tests (8)

Acceptability: Organisms randomly assigned to containers (1), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Pimephales promelas

Study: Belden JB, Lydy MJ. 2006. Joint toxicity of chlorpyrifos and esfenvalerate to fathead minnows and midge larvae. Environ Toxicol Chem 25: 623-629.

Relevance

Score: 92.5 (Control not described)

Rating: R

Reliability

Score: 75

Rating: R

Belden & Lydy 2006		
Parameter	Value	Comment
Test method cited	EPA/600/4-91/002	USEPA 1994
Phylum	Chordata	
Class	Actinopterygii	
Order	Cyriniformes	
Family	Cyprinidae	
Genus	<i>Pimephales</i>	
Species	<i>promelas</i>	
Family resides in	North America	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Mobility	
Control response 1	< 10% mortality	
Temperature	21 ± 2° C	
Test type	Static renewal; 24-h renewal	
Photoperiod/light intensity	NR	
Dilution water	Moderately hard synthetic (MHSFW)	
pH	7.8-8.3	
Hardness	MHSFW	
Alkalinity	MHSFW	
Conductivity	MHSFW	
Dissolved Oxygen	> 70%	
Feeding	Twice per day	

Belden & Lydy 2006		
Parameter	Value	Comment
Purity of test substance	> 98%	
Concentrations measured?	No, but stability confirmed in separate study	
Measured is what % of nominal?	90% pre-test; 85% post-test	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None	
Concentration 1 Nom/Meas (µg/L)	NR	Reps and #: 4 w 10 per
Concentration 2 Nom/Meas (µg/L)	NR	Reps and #: 4 w 10 per
Concentration 3 Nom/Meas (µg/L)	NR	Reps and #: 4 w 10 per
Concentration 4 Nom/Meas (µg/L)	NR	Reps and #: 4 w 10 per
Concentration 5 Nom/Meas (µg/L)	NR	Reps and #: 4 w 10 per
Control	Not described; presumably dilution water	Reps and #: 4 w 10 per
ECx (95% C.I.)	EC10: 110 (80-130) µg/L EC50: 200 (180-230) µg/L	Log-probit

Reliability points taken off for:

Documentation: Control type (8), Nominal concentrations (3), Measured concentrations (3), Hardness (2), Alkalinity (2), Photoperiod (3), Hypothesis tests (8)

Acceptability: Control appropriate (6), Feeding (3), Photoperiod (2), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Pimephales promelas

Study: Geiger DL, Call DJ, Brooke LT. 1988. Acute toxicities of organic chemicals to fathead minnows (*Pimephales promelas*) Volume IV. Center for Lake Superior Environmental Studies. University of Wisconsin-Superior, Superior, WI. pp. 195-197.

Relevance

Score: 90 (No standard method)

Rating: R

Reliability

Score: 82.5

Rating: R

Notes: Test 1 and Test 2 summarized here

Geiger et al. 1988		
Parameter	Value	Comment
Test method cited	None cited, but compares to EPA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	<i>Pimephales</i>	
Species	<i>promelas</i>	
Family resides in	N. America	
Age/size at start of test/growth phase	Test 1: 32 d Test 2: 44 d	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96 h	
Data for multiple times?	Yes for test 1, raw data given	
Effect 1	Mortality	
Control response 1	Test 1: 0% Test 2: 0%	
Temperature	Test 1: 25.1 ± 0.41 °C Test 2: 16.3 ± 0.5 °C	
Test type	Flow-thru	
Photoperiod	NR	
Dilution water	Filtered Lake Superior water or dechlorinated tapwater	chemical parameters very similar
pH	Test 1: 7.2 ± 0.9 Test 2: 7.5 ± 0.03	

Geiger et al. 1988		
Parameter	Value	Comment
Hardness	Test 1: 46 ± 0.5 mg/L; Test 2: 44.4 ± 0.29 mg/L	As CaCO ₃
Alkalinity	Test 1: 41.6 ± 0.5 mg/L; Test 2: 47.0 ± 3.21 mg/L	As CaCO ₃
Conductivity	NR	
Dissolved Oxygen	Test 1: 7.4 ± 0.19 ; Test 2: 8.1 ± 1.20	
Feeding	None	
Purity of test substance	99.9%	
Concentrations measured?	Yes	
Measured is what % of nominal?	NR	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Meas (µg/L)	Test 1: 45.1-48.1; Test 2: 160-175	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Concentration 2 Meas (µg/L)	Test 1: 69.1-71.1; Test 2: 256-262	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Concentration 3 Meas (µg/L)	Test 1: 115-130; Test 2: 258-265	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Concentration 4 Meas (µg/L)	Test 1: 210-230; Test 2: 421-447	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Concentration 5 Meas (µg/L)	Test 1: 370-395; Test 2: 544-840	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
Control	1-1.5 µg/L chlorpyrifos in dilution water	Reps: 2 w/50 per (test 1); 2 w/10 per (test 2)
LC50 (95% C.I.); µg/L	Test 1: 200 (190-220); Test 2: 506 (231-1110)	Trimmed Spearman-Kärber

Other data: Could be used for acute-to-chronic estimation if no measured chronic data are available.

Raw mortality data for test 1 by replicate (no. dead out of 50):

Hr	Ct1	Ct2	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2
24	0	0	0	3	3	0	3	1	15	12	33	28
48	0	0	0	0	3	0	3	1	17	22	43	41
72	0	0	0	0	3	1	4	1	23	27	47	46
96	0	0	0	0	3	1	4	1	30	31	48	47

Reliability points taken off for:

Documentation: Nominal concentrations (3), Conductivity (2), Photoperiod (3), Hypothesis tests (8).

Acceptability: Acceptable standard method (5), Measured concentrations within 20% Nom (4), Appropriate age/size (3), Conductivity (1), Photoperiod (2), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Pimephales promelas

Study: Holcombe GW, Phipps GL, Tanner DK. 1982. The acute toxicity of kelthane, dursban, disulfoton, pydirn, and permethrin to fathead minnows *Pimephales promelas* and rainbow trout *Salmo gairdneri*. Environ Poll (Series A) 29: 167-178.

Relevance

Score: 100

Rating: R

Reliability

Score: 91.5

Rating: R

Notes: 24-, 48-, 72- and 96-h LC50s reported

Holcombe et al. 1982		
Parameter	Value	Comment
Test method cited	USEPA 1975	Cited for "procedures and methods not specified" in text
Phylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	<i>Pimephales</i>	
Species	<i>promelas</i>	
Family resides in	North America	
Age/size at start of test/growth phase	31-32 d; 0.1 g	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96-h	
Data for multiple times?	Yes, but no raw data	
Effect 1	Mortality	
Control response 1	NR	
Effect 2	Equilibrium	
Effect 3	Behaviour	
Effect 4	Deformities	
Temperature	25.1 ± 1.3 °C	
Test type	Flow-through	Glass tanks; 74 ml/min flow with 90% replacement every 9 h

Holcombe et al. 1982		
Parameter	Value	Comment
Photoperiod	16L:8D	
Dilution water	Lake Superior water	
pH	7.0-7.4	
Hardness	45.3 (43.7-46.5) mg/L as CaCO ₃	
Alkalinity	41.8 (39.6-43.2) mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	7.3 (6.7-7.7) mg/L	
Feeding	Not fed from 24 h before nor through test	
Purity of test substance	99.9%	
Concentrations measured?	Yes; only measured shown below	
Measured is what % of nominal?	92.7%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Meas (µg/L)	47.0 ± 5.0	Reps: 2 (50 per tank)
Concentration 2 Meas (µg/L)	70.0 ± 3.0	Reps: 2 (50 per tank)
Concentration 3 Meas (µg/L)	122.0 ± 16.0	Reps: 2 (50 per tank)
Concentration 4 Meas (µg/L)	220 ± 35.0	Reps: 2 (50 per tank)
Concentration 5 Meas (µg/L)	383.0 ± 21.0	Reps: 2 (50 per tank)
Number of controls	1 with 2 reps (50 per tank)	No carriers used
LCx; indicate calculation method	24-h LC50 = 320 (285-360); 48-h LC50 = 248 (225-273); 72-h LC50 = 220 (204-236); 96-h LC50 = 203 (191-217)	Replicates combined; Trimmed Spearman Karber; value (95% C.I.) ug/L

Other notes: Fathead minnow schooling behavior disrupted above 47 ug/L from 24 h on. Deformities after 48 h at all concentrations.

USEPA. 1975. The committee on methods for toxicity tests with aquatic organisms. Methods for acute toxicity tests with fish, macroinvertebrates, and amphibians. EPA-660/3-75-009, Duluth MN

Reliability points taken off for:

Documentation: Nominal concentrations (3), Conductivity (2), Hypothesis tests (8)

Acceptability: Control appropriate (6), Control response (9), Measured concentrations within 20% Nom (4), Organisms randomly assigned to containers (1), Organisms properly acclimated/disease free (1), Temperature not held to ± 1°C (3), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Pimephales promelas

Study: Jarvinen AW, Tanner DK. 1982. Toxicity of selected controlled release and corresponding unformulated technical grade pesticides to the fathead minnow *Pimephales promelas*. Environ Poll (Series A). 27: 179-195.

Relevance: Acute

Score: 92.5 (Control response NR)

Rating: R

Reliability

Score: 84

Rating: R

Relevance: Chronic

Score: 100

Rating: R

Reliability

Score: 89

Rating: R

Jarvinen & Tanner 1982		
Parameter	Value	Comment
Test method cited	USEPA 1975 (acute studies); ERL Duluth 1979 (embryo-larval)	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	<i>Pimephales</i>	
Species	<i>promelas</i>	
Family resides in	North America	
Age/size at start of test/growth phase	Newly hatched (4-d tests); Newly hatched (embryo-larval)	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	96-h static; 96-h flow-through acute; 32-d flow-through embryo-larval	
Data for multiple times?	No	
Effect 1	Mortality (static and FT)	
Control response 1	Acute: NR; 32-d exposure: 100%	

Jarvinen & Tanner 1982		
Parameter	Value	Comment
Effect 2	Weight	
Control response 2	NR	
Temperature	23.5-26.0 °C	
Test type	Static (Pyrex beakers) Flow-through	Flow-through at 15 ml/min; 99% replacement in 3 h
Photoperiod	16L:8D	
Dilution water	Lake Superior; sand-filtered, sterilized	
pH	7.4-7.8	
Hardness	45.8 mg/L	
Alkalinity	43.1 mg/L	
Conductivity	NR	
Dissolved Oxygen	Flow-through: > 75% saturation; 6.5-8.4 mg/L in all	
Feeding	Acute: not mentioned; 32-d: 2-3 X daily (nauplii)	
Purity of test substance	Technical: 98.7%; Dursban 10 CR: 10.6%	
Concentrations measured?	Yes	
Measured is what % of nominal?	> 90%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Meas (mg/L)	Acute studies: NR Chronic technical: 0.0009 ± 0.0001; Chronic 10 CR: 0.0007 ± 0.0002	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
Concentration 2 Meas (mg/L)	Acute studies: NR Chronic technical: 0.0016 ± 0.0004 Chronic 10 CR: 0.0013 ± 0.0002	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
Concentration 3 Meas (mg/L)	Acute studies: NR Chronic technical: 0.0032 ± 0.0005; Chronic 10 CR: 0.0022 ± 0.0004	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
Concentration 4 Meas (mg/L)	Acute studies: NR Chronic technical: 0.0057 ± 0.0008; Chronic 10 CR: 0.0048 ±	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per

Jarvinen & Tanner 1982		
Parameter	Value	Comment
	0.0007	
Concentration 5 Meas (mg/L)	Acute studies: NR Chronic technical: 0.0102 ± 0.001 ; Chronic 10 CR: 0.0086 ± 0.0008	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
Control?	0.00007-0.0001 mg/L; no carriers	Reps: Static: 2 w/10 per; 4-d FT: 2 w/20 per; 32-d FT: 2 w/15 per
LC50 (95% C.I.); mg/L	Static, 96-h, technical, un- aged: 0.17 (0- infinity); Static, 96-h, technical, aged: 0.15 (0.12-0.29); Static, 96-h, 10 CR, un- aged: 0.13 (0-infinity); Static, 96-h, 10 CR, aged: 0.28 (0.22-0.36); FT, 96-h, technical: 0.14 (0.12-0.16); FT, 96-h, 10 CR: 0.12 (0.11-0.13)	Moving average
NOEC; (32-d FT); mg/L	Survival, technical: 0.0032; Weight, technical: 0.0016; Survival, 10 CR: 0.0022; Weight, 10 CR: 0.0022	ANOVA; Dunnett's
LOEC; mg/L	Survival, technical: 0.0057; Weight, technical: 0.0032; Survival, 10 CR: 0.0048; Weight, 10 CR: 0.0048	
MATC (GeoMean NOEC,LOEC)	Survival, technical: 0.0043; Weight, technical: 0.0023; Survival, 10 CR: 0.0032; Weight, 10 CR: 0.0032	
% of control at NOEC	Survival, technical: 90%; Weight, technical: 101%; Survival, 10 CR: 90%; Weight, 10 CR: 94%	
% of control at LOEC	Survival, technical: 86%; Weight, technical: 84%; Survival, 10 CR: 61.2%; Weight, 10 CR: 68%	

Other data:

$t_{1/2} = 41$ d for technical grade; determined in static half-life studies using Lake Superior water separate from tox studies
 $t_{1/2} = > 200$ d for 10 CR

Acute test: Reliability points taken off for:

Documentation: Nominal concentrations (3), Measured concentrations (3), Hypothesis tests (8)

Acceptability: Control response (9), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Random or block design (2), Appropriate spacing between concentrations (2), Hypothesis tests (3)

Chronic test: Reliability points taken off for:

Documentation: Nominal concentrations (3), MSD (2), Point estimates (8)

Acceptability: Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Random or block design (2), MSD (1), LC/EC values (3)

Toxicity Data Summary

Pimephales promelas

Study: Phipps G L, Holcombe GW. 1985. A method for acute multiple species toxicant testing: acute toxicity of 10 chemicals to 5 vertebrates and 2 invertebrates. Environ Poll (Series A) 38: 141-157.

Relevance

Score: 100

Rating: R

Reliability

Score: 91.5

Rating: R

Notes: Multispecies exposure generating LC50s for each species. Not a multispecies test that is environmentally realistic because species were isolated from each other. Doesn't count as a mesocosm study due to lack of interaction.

Phipps & Holcombe 1985		
Parameter	Value	Comment
Test method cited	New multispecies method based on ASTM, EPA, APHA methods	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	<i>Pimephales</i>	
Species	<i>promelas</i>	
Family resides in	North America	
Age/size at start of test/growth phase	0.5 g	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	96 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	0 in a separate test of 3680 mg/L dimethylformamide; NR in tests	
Temperature	17.3 ± 0.6 °C	
Test type	Flow-through	90% replacement in 8 h; 130 ml/min

Phipps & Holcombe 1985		
Parameter	Value	Comment
Photoperiod	16L:8D	
Dilution water	Lake Superior	
pH	7.1-7.8	
Hardness	44.4 (range 40.7-46.6) mg/L as CaCO ₃	
Alkalinity	45.4 (range 42.3-57.0) mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	7.5 ± 1.6 mg/L (range 4.7-10.0); ≥ 50% saturation	mean ± sd
Feeding	None	
Purity of test substance	NR	
Concentrations measured?	Yes; average 99.5% of nominal; Measured concentrations ranged from 0.004-0.806 mg/L	Table 1 lists 3 different sets of Dursban measured concentrations, but only one Dursban test was done
Measured is what % of nominal?	99.5%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	108 mg/L dimethylformamide	
Concentration 1 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 2 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 3 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 4 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Concentration 5 Nom/Meas (µg/L)	See above	Reps: 2 w/20 per
Control?	Solvent control; 108 mg/L dimethylformamide	Reps: 2 w 20 per
LC50 (95% C.I.)	96-h: 0.542 (0.225-1.31) mg/L	Trimmed Spearman-Kärber

Reliability points taken off for:

Documentation: Nominal Concentrations (3), Conductivity (2), Hypothesis tests (8)

Acceptability: Organisms randomly assigned to containers (1), Conductivity (1), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Pimephales promelas

Study: Jarvinen AW, Nordling BR, Henry ME. 1983. Chronic toxicity of Dursban (chlorpyrifos) to the fathead minnow (*Pimephales promelas*) and the resultant acetylcholinesterase inhibition. *Ecotoxicol Environ Saf* 7: 423-434.

Relevance: 1st gen. survival

Score: 92.5

Rating: R

Reliability

Score: 81

Rating: R

Relevance: others

Score: 100

Rating: R

Reliability

Score: 85.5

Rating: R

Jarvinen et al. 1983		
Parameter	Value	Comment
Test method cited	Benoit 1981 (EPA-600/8-81-011)	
Phylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	<i>Pimephales</i>	
Species	<i>promelas</i>	
Family resides in	North America	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	30, 60, 136, 200 d	
Data for multiple times?	Yes	
Effect 1	Survival	
Control response 1	1 st generation: NR 2 nd generation (30d): 100 ± 0%	
Effect 2	Growth (length mm)	
Control response 2	30-d: 26.5 ± 2.8; 60-d: 33.6 ± 3.6;	

Jarvinen et al. 1983		
Parameter	Value	Comment
	136-d: 49.7 ± 4.9 ; 200-d: 62.6 ± 7.9	
Effect 3	2 nd generation growth (weight mg; length mm)	
Control Response 3	191 ± 49.8 mg; 29.1 ± 2.5 mm	
Effect 4	Maturation rate	
Control response 4	NR	
Effect 5	Mean spawns per spawning pair	
Control response 5	8.0 ± 1.4	
Effect 6	Mean eggs per spawn per spawning pair	
Control response 6	150.1 ± 57.2	
Effect 7	Total egg production	
Control response 7	5003 ± 1126	
Effect 8	Embryo hatchability	
Control response 8	95.4 ± 1.7	
Effect 9	Normal (lack of deformities); 2 nd generation	
Control response 9	$100 \pm 0\%$	
Effect 10	2 nd generation viable biomass (g)	
Control response 10	902 ± 99.2 g	
Effect 11	AChE inhibition	
Control response 11	NR	
Temperature	24.3-25.9 °C	
Test type	Flow-through	99% turnover per 10 h
Photoperiod	16L:8D	
Dilution water	Sand-filtered, sterilized Lake Superior	
pH	7.2-7.7	
Hardness	43.1 mg/L	
Alkalinity	41.9 mg/L	
Conductivity	NR	
Dissolved Oxygen	> 75% saturation; 6.3-8.7 mg/L	
Feeding	Brine shrimp daily; excess siphoned out	
Purity of test substance	Not given for Dursban formulation; technical grade: 98.7%	Dursban 10 CR

Jarvinen et al. 1983		
Parameter	Value	Comment
Concentrations measured?	Yes	
Measured is what % of nominal?	67-89%; mean = 78.7%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	None used	
Concentration 1 Nom/Meas (µg/L)	0.18/0.12 ± 0.02 (sd)	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2 nd gen studies; 10 for 60 d AChE
Concentration 2 Nom/Meas (µg/L)	0.37/0.27 ± 0.06	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2 nd gen studies; 10 for 60 d AChE
Concentration 3 Nom/Meas (µg/L)	0.75/0.63 ± 0.09	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2 nd gen studies; 10 for 60 d AChE
Concentration 4 Nom/Meas (µg/L)	1.50/1.21 ± 0.15	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2 nd gen studies; 10 for 60 d AChE
Concentration 5 Nom/Meas (µg/L)	3.00/2.68 ± 0.26	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2 nd gen studies; 10 for 60 d AChE
Control	Dilution water	Reps: 35 from 0-60 d; 25 from 60-200; 25 for 2 nd gen studies; 10 for 60 d AChE
NOEC; method not indicated	1 st gen survival between 30 and 60 d: 1.21 ug/L; 30 d growth: 1.21 ug/L; 60 d growth: 0.63 ug/L; 136 d growth: 1.21 ug/L; 200 d growth: 2.68 ug/L; 136 d maturation: < 0.12 ug/L; Mean spawns per spawning pair: 1.21 ug/L; Mean eggs per spawn per spawning pair: 1.21 ug/L; Total egg production: 0.27 ug/L; Embryo hatchability: 1.21 ug/L; 2 nd gen survival: 2.68 ug/L; 2 nd gen normal: 1.21 ug/L; 2 nd gen weight: 0.63 ug/L; 2 nd gen length: 0.63 ug/L;	2 nd gen survival, normalcy, growth is at 30 d.

Jarvinen et al. 1983		
Parameter	Value	Comment
	2 nd gen biomass: < 0.012 ug/L 60-d AChE inhibition: 0.012 ug/L	
LOEC	1 st gen survival between 30 and 60 d: 2.68 ug/L; 30 d growth: 2.68 ug/L; 60 d growth: 1.21 ug/L; 136 d growth: 2.68 ug/L; 200 d growth: > 2.68 ug/L; 136 d maturation: 0.12 ug/L; Mean spawns per spawning pair: 2.68 ug/L; Mean eggs per spawn per spawning pair: 0.63 ug/L; Total egg production: 0.63 ug/L; Embryo hatchability: 2.68 ug/L; 2 nd gen survival: > 2.68 ug/L; 2 nd gen normal: 2.68 ug/L; 2 nd gen weight: 1.21 ug/L; 2 nd gen length: 1.21 ug/L; 2 nd gen biomass: 0.012 ug/L 60-d AChE inhibition: < 0.012 ug/L	
MATC (GeoMean NOEC,LOEC)	1 st gen survival between 30 and 60 d: 1.80 ug/L; 30 d growth: 1.80 ug/L; 60 d growth: 0.87 ug/L; 136 d growth: 1.80 ug/L; 200 d growth: NC; 136 d maturation: NC; Mean spawns per spawning pair: 1.80 ug/L; Mean eggs per spawn per spawning pair: 0.87 ug/L; Total egg production: 0.41 ug/L; Embryo hatchability: 1.80 ug/L; 2 nd gen survival: NC; 2 nd gen normal: 1.80 ug/L; 2 nd gen weight: 0.87 ug/L; 2 nd gen length: 0.87 ug/L; 2 nd gen biomass: NC; 60-d AChE inhibition: NC	
Difference from control at NOEC	1 st gen survival between 30 and 60 d: NC 30 d growth: 98% 60 d growth: 99% 136 d growth: 97% 200 d growth: 91% 136 d maturation: NC Mean spawns per spawning pair: 54% Mean eggs per spawn per spawning pair: 72%	Mean eggs per spawn: interrupted dose response; LOEC is lower than NOEC; Same for 2 nd gen weight and length

Jarvinen et al. 1983		
Parameter	Value	Comment
	Total egg production: 56% Embryo hatchability: 94% 2 nd gen survival: 54% 2 nd gen normal: 945 2 nd gen weight: 94% 2 nd gen length: 99% 2 nd gen biomass: NC 60-d AChE inhibition: 0-10%	Values in bold indicate effects that are too large at the NOEC
Difference from control at LOEC	1 st gen survival between 30 and 60 d: NC 30 d growth: 84.5% 60 d growth: 95.8% 136 d growth: 81.7% 200 d growth: NC 136 d maturation: 25% Mean spawns per spawning pair: 28.8% Mean eggs per spawn per spawning pair: 55.5% Total egg production: 36% Embryo hatchability: 87% 2 nd gen survival: NC 2 nd gen normal: 24% 2 nd gen weight: 91% 2 nd gen length: 97% 2 nd gen biomass: 46.5% 60-d AChE inhibition: 21-41%	

Reliability points taken off for:

Documentation: Conductivity (2), Statistical methods identified (5), Point estimates (8)

Acceptability: Control response (9, for 1st generation survival only), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Conductivity (1), Random or block design (2), Appropriate statistical method (2), Hypothesis tests (3), Point estimates (3)

Toxicity Data Summary

Pimephales promelas

Mayes M, Weinberg J, Rick D, Martin MD.1993. Chlorpyrifos: A Life cycle Toxicity Test with the Fathead Minnow, *Pimephales promelas* Rafinesque: Lab Project Number; ES-DR-0043-4946-9: DECO-ES-2557B. Unpublished study prepared by The Environmental Toxicology & Chemistry Research Lab. 108p. MRID 428344-01 (on CD)

Relevance

Score: 100

Rating: R

Reliability

Score: 93

Rating: R

Mayes et al., 1993		
Parameter	Value	Comment
Test method cited	USEPA	
Phylum/subphylum	Chordata	
Class	Actinopterygii	
Order	Cypriniformes	
Family	Cyprinidae	
Genus	<i>Pimephales</i>	
Species	<i>promelas</i>	
Native to	North America	
Age/size at start of test/growth phase	<24hr egg	
Source of organisms	in-house laboratory culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	Yes	
Test vessels randomized?	Yes	
Test duration	242 days	Fo+F1 full lifecycle
Data for multiple times?	Yes	
Chronic effect 1	Fo & F1 Survival	Significant effects
Control response 1	Fo 100%, d12-25; F1 100-93.8 %, 8-32d	
Chronic effect 1	Fo & F1 Growth	Interrupt. dose-resp.
Control response 1	2.3g, 28.31cm	
Other Effects	Fo:Total spawns, Total of eggs, Hatchability, Day to final hatch, +same for F1	No statistically significant responses
Temperature	25.0 - 25.5	
Test type	Chronic -flow thru	
Photoperiod/light intensity	16:8	Cool white flrscent.

Mayes et al., 1993		
Parameter	Value	Comment
		(1025-1252 LUX)
Dilution water	Upper Saginaw Bay of Lake Huron, city treated, then sand filtered, carbon filtered, UV irradiated, pH adjusted with CO2	
pH	7.0-8.1	
Hardness	73.8 mg CaCO3/L	
Alkalinity	49.1 mg CaCO3/L	
Conductivity	181.5 umhos/cm	
Dissolved Oxygen	7.8 mg/L	
Feeding	Yes daily, 1-3 times	
Purity of test substance	99.7%	
Concentrations measured? (ug/L)	Yes	
Measured is what % of nominal?	Chronic: 117.8+/-8.3 %	
Chemical method documented?	GC/ECD	
Concentration of carrier (if any) in test solutions	max. <0.1 mL/L	acetone
Concentration 1 Nom/Meas (ug/L)	0.063/ 0.0826	2 reps with 40 fish per aquaria
Concentration 2	0.125/ 0.1438	
Concentration 3	0.250/ 0.3001	
Concentration 4	0.500/ 0.5683	
Concentration 5	1.000/1.0932	
Control	Water only + solvent (acetone)	
NOEC; ug/L	0.568 ug/L	
LOEC; ug/L	1.093: Fo mort. -d12, 19, 25 1.093: F1 mort. -d 8-32	ANOVA w/ Dunnett's Test
MATC (GeoMean NOEC,LOEC)	0.788 ug/L	
% control at NOEC	F0: d12-25 --- 97.5 % F1: d 8-32 --- 100 -92%	
% of control LOEC	F0: d12-25 --- 86.25 % F1: d 8-32 --- 69 -65 %	

Notes: other significant effects, but either transient response, only when compared to solvent control (vs. water only), or interrupted dose response

0.568: % hatch - 4d -transient response

0.300: growth -d61- not sig. compared to water only +interrupted dose response

0.568: adult growth -interrupted dose response

Reliability points taken off for: Documentation: MSD (2), Point estimates (8);

Acceptability: MSD (1), Point estimates (3)

Toxicity Data Summary

Procloeon sp.

Study: Anderson BS, Phillips BM, Hunt JW, Connor V, Richard N, Tjeerdema RS. 2006. Identifying primary stressors impacting macroinvertebrates in the Salinas River (California, USA): Relative effects of pesticides and suspended particles. Environ Poll 141: 402-408.

Details of control survival and LC₅₀s for individual tests taken from original laboratory data sheets provided by the authors.

Relevance

Score: 100 for test 2; 92.5 for tests 1 and 3 (control survival < 90%)

Rating: R for all tests

Reliability

Score: 85.5 for test 1; 88.5 for test 2; 85.5 for test 3

Rating: R for all tests

Anderson et al. 2006		
Parameter	Value	Comment
Test method cited	USEPA 1993	Pers. Comm.; full reference below
Phylum	Arthropoda	
Class	Insecta	
Order	Ephemeroptera	
Family	Baetidae	
Genus	<i>Procloeon</i>	
Species	sp.	
Found in	N. America	
Age/size at start of test/growth phase	0.5-1cm (age unknown)	
Source of organisms	Field collected from clean site	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	48 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	Test 1: 84% Test 2: 96% Test 3: 84%	Results for methanol controls

Anderson et al. 2006		
Parameter	Value	Comment
Temperature	21.3°C	From data sheet
Test type	Static renewal; daily	
Photoperiod/light intensity	NR	
Dilution water	Well water	
pH	7.5-7.9	From data sheet
Hardness	NR	
Alkalinity	NR	
Conductivity	683-721 µS/cm	From data sheet
Dissolved Oxygen	7.5-8.4 mg/L	From data sheet
Feeding	None	
Purity of test substance	99%	
Concentrations measured?	Yes	
Measured is what % of nominal?	97% (range: 79-118%)	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	1% methanol (10 mL/L)	
Concentration 1 Nom/Meas (µg/L)	Test 1: NA Test 2: 0.063/0.06 Test 3: 0.063/0.054	Reps: 3-5 w/5 per
Concentration 2 Nom/Meas (µg/L)	Test 1: 0.125/0.087 Test 2: 0.125/0.097 Test 3: 0.125/0.101	Reps: 3-5 w/5 per
Concentration 3 Nom/Meas (µg/L)	Test 1: 0.25/0.215 Test 2: 0.25/0.23 Test 3: 0.25/0.272	Reps: 3-5 w/5 per
Concentration 4 Nom/Meas (µg/L)	Test 1: 0.5/0.527 Test 2: 0.5/0.615 Test 3: 0.5/0.569	Reps: 3-5 w/5 per
Control	Dilution water; 1% methanol	Reps: 3-5 w/5 per
LC50; µg/L	Test 1: 0.1791 Test 2: 0.0704 Test 3: 0.0798	Trimmed Spearman-Kärber
NOEC: µg/L	Test 1: 0.087 Test 2: < 0.06 Test 3: .054	ANOVA; Dunnett's; p = 0.05; Test 1 MSD = 0.30 Test 2 MSD = 0.269 Test 3: MSD = 0.239

Anderson et al. 2006		
Parameter	Value	Comment
LOEC: µg/L	Test 1: 0.215 Test 2: 0.06 Test 3: 0.101	
MATC: µg/L	Test 1: 0.137 Test 2: NC Test 3: 0.074	
% of control at NOEC	Test 1: 81% Test 2: NC Test 3: 100%	
% of control at LOEC	Test 1: 43% Test 2: 71% Test 3: 9.5%	

USEPA. 1993. Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms. Fourth edition. Weber, C. I., ed. Environmental Monitoring Systems Laboratory, Office of Research and Development, United States Environmental Protection Agency, Cincinnati, OH.

Reliability points taken off for:

Documentation: Hardness (2), Alkalinity (2), Photoperiod (3), % Control at NOEC (2, Test 2 only)

Acceptability: Control response (9, Test 2 OK), Carrier solvent ≤ 0.5 mL/L (4), Hardness (2), Alkalinity (2), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Photoperiod (2), NOEC response reasonable (1, Test 2 only)

Toxicity Data Summary

Pungitius pungitius

Study: Van Wijngaarden R, Leeuwangh P, Lucassen WGH, Romijn K, Ronday R, Van Der Velde R, Willigenburg W. 1993. Acute toxicity of chlorpyrifos to fish, a newt, and aquatic invertebrates. Bull Environ Contam Toxicol 51: 716-723.

Relevance

Score: 90 (No standard method)

Rating: R

Reliability

Score: 76

Rating: R

Van Wijngaarden et al. 1993		
Parameter	Value	Comment
Test method cited	No standard method cited	
Phylum	Chordata	
Class	Actinopterygii	
Order	Gasterosteiformes	
Family	Gasterosteidae	
Genus	<i>Pungitius</i>	
Species	<i>pungitius</i>	
Family resides in	North America	
Age/size at start of test/growth phase	Adult	
Test duration	48, 96 h	
Source of organisms	Ditches	
Have organisms been exposed to contaminants?	NR	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	< 10%	
Temperature	19 ± 0.8 °C	
Test type	Discontinuous flow-through; 1.85 L/h	
Photoperiod	14L:10D	
Dilution water	Tapwater	
pH	6.6-8.2	
Hardness	110 mg/L as CaCO ₃	
Alkalinity	NR	
Conductivity	NR	
Dissolved Oxygen	3.6-7.7 mg/L	on excursion to 1.1

Van Wijngaarden et al. 1993		
Parameter	Value	Comment
		mg/L in control; no apparent effects
Feeding	Daily; dry food and guppies	
Purity of test substance	99.8%	
Concentrations measured?	Yes	
Measured is what % of nominal?	99.4%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	≤ 0.1 mL/L acetone	
Concentration 1-5 or 6 Meas ($\mu\text{g/L}$)	0.6-13.9; factor of 2 between concentrations	Reps: 1? w/10 per
Control	Tapwater; separate carrier tests showed no toxicity	Reps: 1? w/10 per
LCx (95% C.I.); $\mu\text{g/L}$; based on mean concentrations measured daily	48-h LC10: 2.3 (1.2-5.5); 48-h LC50: 5.7 (4.4-7.5); 96-h LC10: 2.1 (1.3-4.6); 96-h LC50: 4.7 (3.6-6.0)	Log-log regression

Other notes: test was duplicated; the text is confusing as to how many replicates were in each test; it appears that the tests may have been done with one replicate per concentration.

Reliability points taken off for:

Documentation: Nominal concentrations (3), Alkalinity (2), Conductivity (2), Hypothesis tests (8)

Acceptability: Acceptable standard method (5), Appropriate age/size (3), No prior contaminant exposure (4), Feeding (3), Dilution water source (2), Alkalinity (2), Dissolved Oxygen (6), Conductivity (1), Random or block design (2), Adequate number of concentrations (2), Hypothesis tests (3)

Toxicity Data Summary

Simulium vittatum IIL-1

Study: Hyder AH, Overmyer JP, Noblet R. 2004. Influence of developmental stage on susceptibilities and sensitivities of *Simulium vittatum* IS-7 and *Simulium vittatum* IIL-1 (Diptera: Simuliidae) to chlorpyrifos. Environ Toxicol Chem 23: 2856-2862.

Relevance

Score: 100

Rating: R

Reliability

Score: 84

Rating: R

Hyder et al. 2004		
Parameter	Value	Comment
Test method cited	ASTM (1992); E 729-88a	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Simuliidae	
Genus	<i>Simulium</i>	
Species	<i>vittatum</i> IIL-1	
Family resides in	North America	
Age/size at start of test/growth phase	1) 4 th and 5 th instar; 2) 6 th and 7 th instar	Eggs collected from contaminated site
Source of organisms	Field	
Have organisms been exposed to contaminants?	Yes	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	24 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	< 10%	
Temperature	19 °C	
Test type	Static on orbital shaker	
Photoperiod	NR	
Dilution water	Moderately hard water	
pH	7.6	
Hardness	86.8 mg/L as CaCO ₃	
Alkalinity	64.8 mg/L as CaCO ₃	
Conductivity	NR	
Dissolved Oxygen	68%	
Feeding	None	

Hyder et al. 2004		
Parameter	Value	Comment
Purity of test substance	98%	
Concentrations measured?	Yes	
Measured is what % of nominal?	72.58-94%; mean = 83.3%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR	
Concentration Range Meas; (µg/L); 5 concentrations	4 th & 5 th instar: 0.08-1.28; 6 th & 7 th instar: 0.2-3.2	Reps: 5 w/15 per
Control	Acetone control; concentration not reported, but no adverse effects in controls	3 controls w/ 5 reps each w/ 15 per
LC50 (se); ug/L; mean of 3 tests	4 th & 5 th instar: 0.13 (0.01); 6 th & 7 th instar: 0.91 (0.16)	Probit with Abbott's correction for control mortality

Reliability points taken off for:

Documentation: Nominal concentrations (3), Conductivity (2), Photoperiod (3), Hypothesis tests (8)

Acceptability: Carrier solvent ≤ 0.5 mL/L (4), Organisms randomly assigned to containers (1), Temperature not held to $\pm 1^{\circ}\text{C}$ (3), Conductivity (1), Photoperiod (2), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Simulium vittatum IS-7

Study: Hyder AH, Overmyer JP, Noblet R. 2004. Influence of developmental stage on susceptibilities and sensitivities of *Simulium vittatum* IS-7 and *Simulium vittatum* IIL-1 (Diptera: Simuliidae) to chlorpyrifos. Environ Toxicol Chem 23: 2856-2862.

Relevance

Score: 100

Rating: R

Reliability

Score: 84

Rating: R

Hyder et al. 2004		
Parameter	Value	Comment
Test method cited	ASTM (1992); E 729-88a	
Phylum	Arthropoda	
Class	Insecta	
Order	Diptera	
Family	Simuliidae	
Genus	<i>Simulium</i>	
Species	<i>vittatum</i> IS-7	
Family resides in	North America	
Age/size at start of test/growth phase	1) 2 nd and 3 rd instar; 2) 4 th and 5 th instar; 3) 6 th and 7 th instar	Laboratory cultures
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	Possibly	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	24 h	
Data for multiple times?	No	
Effect 1	Mortality	
Control response 1	< 10%	
Temperature	19 °C	
Test type	Static on orbital shaker	
Photoperiod	NR	
Dilution water	Moderately hard water	
pH	7.6	
Hardness	86.8 mg/L as CaCO ₃	
Alkalinity	64.8 mg/L as CaCO ₃	
Conductivity	NR	

Hyder et al. 2004		
Parameter	Value	Comment
Dissolved Oxygen	68%	
Feeding	None	
Purity of test substance	98%	
Concentrations measured?	Yes	
Measured is what % of nominal?	72.58-94%; mean = 83.3%	
Chemical method documented?	Yes	
Concentration of carrier (if any) in test solutions	NR	
Concentration Range Meas; (µg/L); 5 concentrations	2 nd & 3 rd instar: 0.008-0.128; 4 th & 5 th instar: 0.08-1.28; 6 th & 7 th instar: 0.2-3.2	Reps: 5 w/15 per
Control	Acetone control; concentration not reported, but no adverse effects in controls	3 controls w/ 5 reps each w/ 15 per
LC50 (se); ug/L; mean of 3 tests	2 nd & 3 rd instar: 0.06 (0.02) 4 th & 5 th instar: 0.11 (0.13); 6 th & 7 th instar: 0.68 (0.19)	Probit with Abbott's correction for control mortality

Reliability points taken off for:

Documentation: Nominal concentrations (3), Conductivity (2), Photoperiod (3), Hypothesis tests (8)

Acceptability: Carrier solvent ≤ 0.5 mL/L (4), Organisms randomly assigned to containers (1), Temperature not held to $\pm 1^\circ\text{C}$ (3), Conductivity (1), Photoperiod (2), Random or block design (2), Hypothesis tests (3)

Toxicity Data Summary

Xenopus laevis

Study: El-Merhibi A, Kumar A, Smeaton T. 2004. Role of piperonyl butoxide in the toxicity of chlorpyrifos to *Ceriodaphnia dubia* and *Xenopus laevis*. *Ecotox Environ Safety* 57: 202-212.

Relevance

Score: 100

Rating: R

Reliability

Score: 74 for acute; 71 for chronic

Rating: R for acute; L for chronic

El-Merhibi et al. 2004		
Parameter	Value	Comment
Test method cited	ASTM FETAX 1998;	
Phylum	Chordata	
Class	Amphibia	
Order	Anura	
Family	Pipidae	
Genus	<i>Xenopus</i>	
Species	<i>laevis</i>	
Found in	North America	
Age/size at start of test/growth phase	< 24 h	
Source of organisms	Lab culture	
Have organisms been exposed to contaminants?	No	
Animals acclimated and disease-free?	Yes	
Animals randomized?	NR	
Test vessels randomized?	NR	
Test duration	Acute: 96 h Chronic: 10 d	
Data for multiple times?	Yes	
Effect 1	Mortality	
Control response 1	< 10%	
Effect 2	AChE inhibition	
Control response 2	Baseline	
Effect 3	Teratogenesis	
Control response 3	None	
Temperature	24.7 ± 5°C	
Test type	Static-renewal; daily	
Photoperiod/light intensity	16L:8D	
Dilution water	Modified FETAX solution (MFS) FETAX = Frog embryo teratogenesis assay: <i>Xenopus</i>	

El-Merhibi et al. 2004		
Parameter	Value	Comment
pH	7.6 ± 0.2	
Hardness	NA	
Alkalinity	NA	
Conductivity	1476 µS/cm	
Dissolved Oxygen	7.4 ± 0.1 mg/L	
Feeding	None in acute test; Wardley's Goldfish Food at renewal interval	
Purity of test substance	99.8%	
Concentrations measured?	No	
Measured is what % of nominal?	NA	
Chemical method documented?	NA	
Concentration of carrier (if any) in test solutions	< 0.1% (1 mL/L); level shown to be non-toxic	
Concentration 1 Nom (µg/L)	5-5000; appears to be 11 concentrations with a dilution factor of 2	Reps: NR, but std method
Control	MFS; solvent (acetone)	Reps: NR, but std method
LC50; µg/L	96 h: 2410 10 d: 92.5	Trimmed Spearman-Kärber
EC50 (95% C.I.); µg/L	96 h malformations: 511 10 d malformations: 35	Trimmed Spearman-Kärber
NOEC; µg/L	96 h mortality: 1280 10 d mortality: 20 96 h malformations: 320 10 d mortality: 20 96 h AChE: 5 10 d AChE: 5	Method: Dunnett's or Bonferroni t-test p: NR MSD: NR
LOEC; indicate calculation method	96 h mortality: 2560 10 d mortality: 40 96 h malformations: 640 10 d mortality: 40 96 h AChE: 10 10 d AChE: 10	Assuming monotonic dose response curve and dilution factor of 2
MATC (GeoMean NOEC,LOEC)	96 h mortality: 1810 10 d mortality: 28 96 h malformations: 450 10 d mortality: 28 96 h AChE: 7.1 10 d AChE: 7.1	Assuming monotonic dose response curve and dilution factor of 2
% control at NOEC	NC; data not provided	

Reliability points taken off for:

Documentation: Analytical method (4), Measured concentrations (3), Hardness (2), Alkalinity (2), Hypothesis tests (8)

Acceptability: Measured concentrations within 20% Nom (4), Carrier solvent ≤ 0.5 mL/L (4), Adequate number per replicate (2), Hardness (2), Alkalinity (2), Random or block design (2), Adequate number of concentrations (2), Hypothesis tests (3)

Appendix 4C
Data and calculations for distribution fit test

Chlorpyrifos- Fit test

See Chapter 3 section 3.2.4 for procedure. F-i(xi) calculated with BurliOZ software.

	all LC 50s	Omit one																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	2410	806	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410
	806	178	178	806	806	806	806	806	806	806	806	806	806	806	806	806	806	806
	178	15.96	15.96	15.96	178	178	178	178	178	178	178	178	178	178	178	178	178	178
	15.96	14.1	14.1	14.1	14.1	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96	15.96
	14.1	7.62	7.62	7.62	7.62	7.62	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1
	7.62	6	6	6	6	6	6	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62	7.62
	6	4.7	4.7	4.7	4.7	4.7	4.7	4.7	6	6	6	6	6	6	6	6	6	6
	4.7	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
	0.32	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
	0.25	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	0.22	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.22	0.22	0.22	0.22	0.22	0.22
	0.15	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15
	0.1	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.1	0.1	0.1	0.1
	0.077	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.0654	0.077	0.077	0.077
	0.0654	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.0654	0.0654
	0.06	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.06
	0.035																	
xi		2410	806	178	15.96	14.1	7.62	6	4.7	0.32	0.25	0.22	0.15	0.1	0.077	0.0654	0.06	0.035
5th percentile	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
F-i(xi)		1.77	3.14	6.62	19.19	20.17	25.59	27.96	30.54	66.84	70.48	72.34	77.77	83.18	86.4	88.04	89.24	94.42
		0.018	0.031	0.066	0.192	0.202	0.256	0.28	0.305	0.668	0.705	0.723	0.778	0.832	0.864	0.88	0.892	0.944
1-F(xi)										0.332	0.295	0.277	0.222	0.168	0.136	0.12	0.108	0.056
min		0.018	0.031	0.066	0.192	0.202	0.256	0.28	0.305	0.332	0.295	0.277	0.222	0.168	0.136	0.12	0.108	0.056
pi =2(min)		0.035	0.063	0.132	0.384	0.403	0.512	0.559	0.611	0.663	0.59	0.553	0.445	0.336	0.272	0.239	0.215	0.112

Chlorpyrifos - Fit test continued

pi-value	ln (pi-value)	<u>Fisher test statistic</u>	
		Sum of ln (pi)	X^2_{2n}
0.0354	-3.3410435	43.26284187	0.132595
0.0628	-2.7678002		
0.1324	-2.0219276		
0.3838	-0.9576337		
0.4034	-0.9078267		
0.5118	-0.6698214		
0.5592	-0.5812481		
0.6108	-0.4929857		
0.6632	-0.4106787		
0.5904	-0.526955		
0.5532	-0.5920357		
0.4446	-0.8105803		
0.3364	-1.0894544		
0.272	-1.3019532		
0.2392	-1.4304553		
0.2152	-1.5361875		
0.1116	-2.1928342		

Therefore, distribution fits (no significant lack of fit)

if $X < 0.05$, significant lack of fit
if $X > 0.05$, fit (no significant lack of fit)